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NATURAL HISTORY,

GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON.

VOL. II.

THEORY OF THE EARTH.

Sergei Rayak 1826

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NATURAL HISTORY,

GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON,

ILLUSTRATED WITH ABOVE SIX HUNDRED COPPER PLATES.

THE

HISTORY OF MAN AND QUADRUPEDS

TRANSLATED, WITH NOTES AND OBSERVATIONS,

BY WILLIAM SMELLIE,

MEMBER OF THE ANTIQUARIAN AND ROYAL SOCIETIES OF EDINBURGH.

A NEW EDITION,

CAREFULLY CORRECTED AND CONSIDERABLY ENLARGED, BY MANY ADDITIONAL ARTICLES, NOTES, AND PLATES,

AND

SOME ACCOUNT OF THE LIFE OF M. DE BUFFON.

BY WILLIAM WOOD, F.L.S.

IN TWENTY VOLUMES.

VOL. II.

LONDON:

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ERRATA.

Page 492, *for* "pl. 3, fig. 1." *read* pl. 9, fig. 1.

538, 539, *for* "pl. 12," *read* pl. 14.

565, line 14, *for* "which" *read* what.

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substances thrown out by the mountain, are so great, that they bury whole towns and forests, cover the plains to the thickness of a hundred or two hundred feet, and sometimes form hills and mountains, which are only portions of these matters heaped up and compacted into one mass. The action of the fire and the force of the explosions are so violent, that they produce, by reaction, succussions, which shake the earth, agitate the sea, overturn mountains, and destroy towns and buildings of the most solid materials.

These effects, though natural, have been regarded as prodigies; and, though we often behold in miniature effects similar to those of volcanos; yet grandeur, from whatever source it proceeds, has such an astonishing influence upon the imagination, that it is not surprising they should have been considered by some authors as vents to a central fire, and, by the vulgar, as mouths of hell. Astonishment produces fear, and fear is the source of superstition. The inhabitants of Iceland believe that the groanings of their volcano are the cries of the damned, and that its eruptions are occasioned by the desperation and ungovernable fury of devils and tormented spirits.

All these phænomena, however, are only the effects of fire and of smoke. In the bowels of mountains, there are veins of sulphur, bitumen, and other inflammable substances, together with vast quantities of pyrites, which ferment when exposed to the air or moisture, and produce explosions proportioned to the quantity of in-

flammable matter. This is the true idea of a volcano; and it is easy for the naturalist to imitate the operation of these subterraneous fires. A mixture of sulphur, of filings of iron, and of water, buried at a certain depth below the ground, will exhibit, in miniature, all the appearances of a volcano: this mixture soon ferments to a degree of inflammation, throws off the earth and stones which cover it, and produces explosions every way similar to those of burning mountains.

The most famous volcanos in Europe are those of Mount Ætna in Sicily, of Mount Hecla in Iceland, and of Mount Vesuvius near Naples in Italy. The burning of Mount Ætna is more ancient than the records of history. Its eruptions are extremely violent; and the quantity of matter it throws out is so enormous, that, after digging sixty-eight feet deep, marble pavements, and other vestiges of an ancient city, have been found covered with this amazing load of ejected matter, in the same manner as the town of Herculaneum has been buried with the matter thrown out from Mount Vesuvius. New mouths, or craters, were opened in Ætna in the years 1650, 1669, and at other times. The smoke and flames of this volcano are seen as far as Malta, a distance of sixty leagues: it sends forth a perpetual smoke, and, at particular times, it throws out, with astonishing violence, flames, lava, huge stones, and matter of every kind. An eruption of this volcano, in the year 1537, produced an earthquake over the whole island of Sicily, which

lasted twelve days, and overthrew an immense number of houses and public buildings. It terminated by the bursting of a new mouth, the lava of which burnt up every thing within five leagues of the mountain. It discharged ashes so abundantly, and with such force, that they reached the coast of Italy, and incommoded vessels at great distances from the island. This volcano has, at present, two principal craters, one of which is narrower than the other. They both smoke perpetually; but flames only appear during the time of eruptions *. Large stones, it is said, have been projected from them to the distance of 60,000 paces.

A violent eruption, in 1683, produced a dreadful earthquake in Sicily. It laid the whole city of Catanea in ruins, and destroyed more than 60,000 of its inhabitants, beside those who perished in the neighbouring towns and villages.

Hecla darts its fires through the snows and ice of a frozen climate. Its eruptions, however, are equally violent with those of Ætna, and other volcanos in the more southern regions. It throws out ashes, lava, pumice stones, and sometimes boiling water. The whole island of Iceland abounds in sulphur; but it is not habitable within less than six leagues of the volcano. The history of its most violent eruptions is recorded in a book written by Dithmar Bleffken.

According to historians, the burning of Mount

* Farelli has given a long description of the eruptions of this mountain.

Vesuvius began not before the seventh consulate of Titus Vespasian and Flavius Domitian. The top of the mountain then opened, and at first threw out stones and rocks. These were succeeded by flames and lava which burnt up two neighbouring cities, and volumes of smoke so thick as to darken the light of the sun. The elder Pliny, stimulated by curiosity, approached too near the mountain, and was suffocated by its sulphureous steams *. Dion Cassius relates, that this eruption was so violent, that ashes and sulphureous steams were transported as far as Rome, and across the Mediterranean into Africa and Egypt. Herculaneum was one of the cities that were overwhelmed by the matter ejected from the mountain: it has lately been discovered sixty feet under the surface of the ground, which, in the course of time, had become arable, and fit for every kind of culture. The history of the discovery of Herculaneum is in the hands of the public. We have only to wish, that some person skilled in the knowledge of nature, would examine with attention the different materials which compose these sixty feet of earth, and remark their situation, the alterations they have undergone, the direction they have followed, the hardness they have acquired, &c.

Naples appears to be situated upon a vault, filled with burning minerals; for Vesuvius and Solfatara seem to have subterraneous communications. When Vesuvius throws out lava, Sol-

* See Pliny the Younger's Letter to Tacitus.

fatara emits flames; and, when the eruptions of the former cease, the burning of the latter is likewise extinguished. The city of Naples is nearly in the centre between them.

One of the last and most dreadful eruptions of Vesuvius happened in the year 1737 *. The mountain discharged from several mouths, immense torrents of melted matter, which spread over the fields, and terminated in the sea. M. de Montealegre, who communicated this account of it to the Academy of Sciences, observed, with horror, one of those rivers of fire, which, from its source to the sea, was about seven miles in length, fifty or sixty paces broad, from twenty-five to thirty palms deep, and in the valleys 120 palms. The running matter resembled foam, or the dross which issues from a furnace †, &c.

The ancients have left us some notices concerning the volcanos which were known to them, and particularly those of Ætna and Vesuvius. Several learned and curious observers have in our days examined more minutely the form and effects of these volcanos. On comparing their descriptions, the first observation that presents itself is, the folly of transmitting to posterity the exact topography of these burning mountains. Their form may be said to change daily; their surface rises or sinks in

* This volume was published in the year 1749. Several eruptions have happened since that time.—See Hamilton's History of Vesuvius.

† See l'Hist. de l'Acad. ann. 1737, p. 7.

various places; every eruption produces new gulfs or new eminences: to attempt to describe all these changes, is to follow and paint the successive ruins of a burning edifice. The Vesuvius of Pliny, and the Ætna of Empedocles, present very different aspects from those which have been so ably delineated by Sir William Hamilton and Mr. Brydone; and, in a few ages, these recent descriptions will no longer resemble their objects. Next to the surface of the ocean, nothing on this globe is so fluctuating and inconstant as the surface of volcanic mountains: but even from this inconstancy, and from the variation of form and movements, some general conclusions may be drawn, by bringing particular observations under one point of view.

Of the Changes which have happened in Volcanos.

The base of Ætna is about sixty leagues in circumference, and its perpendicular height about two thousand fathoms above the level of the Mediterranean Sea. We may, therefore, regard this enormous mountain as an obtuse cone, the superficies of which are not less than three hundred square leagues. This conical surface is divided into four zones, situated concentrically above each other. The first is the largest, and, by a gradual ascent, extends above six leagues from the most distant point at the

foot of the mountain. This zone of six leagues broad is almost totally peopled and cultivated. The city of Catania and several villages are situated in this first zone, the surface of which exceeds two hundred and twenty square leagues. The basis of this vast territory consists of various strata of ancient and modern lavas, that have run from different parts of the mountain, from which explosions of subterraneous fires have issued. The surface of this lava, mixed with ashes thrown out from different craters, is converted into a fine soil, which is now sown with grain and planted with vines, except in a few places where the lava is too recent, and still remains uncovered with earth. About the top of the zone, we still see several craters, more or less large and deep, from which the materials issued that have formed the upper stratum or soil.

The second zone commences at the termination of these six leagues. This second zone is an ascent of about two leagues broad. Its declivity is every where more rapid than that of the first zone; and this rapidity augments in proportion as you approach toward the summit. The surface of this second zone is about forty or forty-five square leagues: its whole extent is covered with magnificent forests, and forms a fine belt of verdure to the white and hoary head of this venerable mountain. The soil of these fine forests is nothing but lava and ashes converted by the operation of time into excellent earth. What is still more remarkable, the surface of this zone is so unequal, that it

every where presents hills, or rather mountains, all of which have been produced by different eruptions from the summit of Ætna, and other craters below the summit, several of which have formerly acted in this very zone, now converted into forests.

Before arriving at the summit, and after having passed these fine forests, we traverse a third zone, which gives birth to small vegetables only. In winter, this region is covered with snow, which melts in summer. We afterwards meet with a line of permanent snow, which marks the commencement of the fourth zone, and extends to the top of the mountain. These snows and ice occupy about two leagues from the region of small vegetables to the summit, which is likewise covered with snow and ice. Its figure is an exact cone; and it contains the great crater of the volcano, from which are continually discharged immense volumes of smoke. The internal figure of the crater is that of an inverted cone. It is composed of nothing but ashes and other burnt matters thrown out by the mouth of the crater, which is in the centre of the volcano. The external surface of the summit is very rough. The snow is covered with ashes, and the cold is very piercing. On the north side of this region of snow, there are several small lakes, which never freeze. In general, the surface of this last zone is pretty equal, and observes the same declivity, except in a few places; and it is below this region only where we meet with a great number of inequalities, eminences, and

hollows, produced by eruptions, and where we see hills and mountains more or less recently formed, and composed of burnt matters rejected by these different mouths or craters.

In 1770, according to Mr. Brydone, the crater on the top of Ætna was more than a league in circumference; and very different dimensions have been ascribed to it both by ancient and modern authors. All these authors, however, were right; for the dimensions of this mouth of fire have undergone many alterations. All we can infer from the various descriptions that have been given of it, is, that the crater, with its margins, has been four times overturned within these six or seven hundred years. The materials of which it is composed fall back into the bowels of the mountain, are again rejected by fresh eruptions, and form a new crater, which augments and rises by degrees, till it again falls back into the great gulf of the volcano.

The top of the mountain is not the only place from which the subterraneous fire has been discharged. Through the whole territory which forms the sides and ridge of Ætna, and at great distances from the summit, there are many craters, which give passage to the fire, and which are surrounded with broken rocks, that had been discharged by different eruptions. We may even reckon several hills, formed by the eruptions of these small volcanos, which surround the great one. Each of these hills has a crater at its top, in the centre of which is a deep mouth or gulf. Every eruption of Ætna has produced a new

mountain; and, perhaps, Mr. Brydone remarks, their number would determine, better than any other method, that of the eruptions of this famous volcano.

The city of Catania, which is situated at the foot of Mount Ætna, has often been laid in ruins by the lavas which issued from these new mountains during the time of their formation. In ascending from Catania to Nicolosi, we traverse twelve miles through a country formed by ancient lavas, where we see the mouths of extinguished volcanos, which at present are fertile lands, covered with grass, corn, and vineyards. The lavas which form this region proceeded from the eruptions of the small mountains, which are every where dispersed over the sides of Ætna: they are all, without exception, either regular hemispheres or cones. In general, every eruption raised one of these mountains. Hence the action of the subterraneous fires does not always reach the summit of Ætna. They often issue from the sides, and even from the foot of this burning mountain. Each eruption from the sides of Ætna commonly produces a new mountain, composed of rocks, stones, and ashes, projected to a great distance by the force of the fire; and the magnitude of these new mountains is proportioned to the duration of the eruption. If it continues but a few days, it produces only a little hill, about a league in circumference at the base, and three or four hundred feet in perpendicular height. But, if the eruption continues some months, like that of 1669, it then gives rise to a

considerable mountain of two or three leagues in circumference, and 900 or 1,000 feet high; and all these hills, produced by Ætna, some of which are 1,200 feet high, appear only as small elevations intended to accompany the majesty of the parent mountain.

In Vesuvius, which is a very small volcano when compared with Ætna, eruptions from the sides of the mountain are rare, and the lava generally issues from the crater at the summit. But, in Ætna, eruptions more frequently proceed from the sides than the top, and lava issues abundantly from every new mountain formed by these eruptions. Mr. Brydone, according to the information he received from M. Recupero, says, that the masses of stones, projected from Ætna, rise to such a height, that they take twenty-one seconds of time in descending to the earth; while those of Vesuvius fall in nine seconds: hence the stones projected by Vesuvius rise to the height of 1,215 feet, and those projected by Ætna rise 6,615 feet; from which we may conclude, if the observations be accurate, that the force of Ætna is to that of Vesuvius as 441 to 81, *i. e.* five or six times greater. That Vesuvius is a very feeble volcano, when compared to Ætna, is proved in a more forcible manner by this circumstance, that Ætna has actually produced other volcanos, which are larger than that of Vesuvius.

" Not a great way from this cavern," says Brydone, " are two of the most beautiful mountains of all that number that spring from Ætna. I mounted

one of our best mules, and, with a good deal of difficulty, arrived at the summit of the highest of them just a little before sun-set. The prospect of Sicily, with the surrounding sea and all its islands, was wonderfully noble. The whole course of the river Semetus, the ruins of Hybla, and several other ancient towns; the rich corn-fields and vineyards on the lower region of the mountain, and the amazing number of beautiful mountains below, made a delightful scene. The hollow craters of these two mountains are each of them considerably larger than that of Vesuvius. They are now filled with stately oaks, and covered to a great depth with the richest soil. I observed that this region of Ætna, like the former, is composed of lava; but this is now covered so deep with earth, that it is no where to be seen, but in the beds of the torrents. In many of these it is worn down by the water to the depth of fifty or sixty feet, and in one of them still considerably more. . . . This conical mountain is of a very great size; its circumference cannot be less than ten miles. Here we took a second rest, as the greatest part of our fatigue still remained. The mercury had fallen to 20 : 4½.—We found this mountain excessively steep; and although it had appeared black, yet it was likewise covered with snow. . . . . The present crater of this immense volcano is a circle of about three miles and a half in circumference. It goes shelving down on each side, and forms a regular hollow, like a vast amphitheatre. From many places of this space, issue volumes of sulphureous smoke,

which, being much heavier than the circumambient air, instead of rising in it, as smoke generally does, immediately on its getting out of the crater, rolls down the side of the mountain like a torrent, till, coming to that part of the atmosphere of the same specific gravity with itself, it shoots off horizontally, and forms a large track in the air, according to the direction of the wind; which, happily for us, carried it exactly to the side opposite to that where we were placed. The crater is so hot, that it is very dangerous, if not impossible to go down into it; besides, the smoke is very incommodious, and, in many places, the surface is so soft, there have been instances of people sinking down in it, and paying for their temerity with their lives. Near the centre of the crater is the great mouth of the volcano . . . . When we arrived at the foot of the cone, we observed some rocks of an incredible size, that have been discharged from the crater. The largest that has been observed from Vesuvius, is a round one of about twelve feet in diameter. These are much greater; indeed almost in proportion of the mountains to each other."

As all that region from the top of Ætna, to the distance of two leagues below, presents an equal surface, without hills or valleys, and as the ruins of Empedocles, the philosopher's tower, who lived 400 years before the Christian æra, are still to be seen, it is probable, that, during all this period, the great crater has made few or no eruptions. Hence the force of the fire

has diminished, as it no longer acts with violence at the summit, and as all the modern eruptions have happened in the lower regions of the mountain. However, within these few centuries, the dimensions of the great crater have been often changed, as appears from the measurements of Sicilian authors at different periods. Sometimes it falls down, and is again gradually elevated till it falls afresh. The first of these fallings, which are well attested, happened in the year 1157, a second in 1329, a third in 1444, and the last in 1669. But, from these facts, we should not conclude, as Mr. Brydone has done, that the crater will soon suffer another overthrow. The notion, that this effect should be produced every hundred years, seems to have no foundation. I should rather imagine, that, as the fire no longer acts with violence at the summit, its force has diminished, and will continue to diminish, in proportion as the sea retires: it has already retired several miles by the action of the volcano, which has formed large banks and bulwarks by vast torrents of lava. Besides, we know, from the diminished rapidity of Scylla and Charybdis, and several other indications, that the Sicilian Sea has sunk considerably within these 2,500 years. We may, therefore, conclude, that this sea will continue to sink, and, of course, that the action of the neighbouring volcanos will not relax; so that the crater of Ætna may remain during a long time in its present state; and, if ever it falls back into the gulf, it will probably be for the last time. I farther

presume, that Ætna ought to be regarded as one of the primitive mountains, on account of its height and the immensity of its size, and that it began to act at the remote period when the waters first retreated. Its action, however, ceased after this retreat, and was not renewed till that modern period when the Mediterranean Sea, being elevated by the rupture of the Bosphorus and the straits of Gibraltar, deluged the land between Sicily and Italy, and approached to the basis of Ætna. Perhaps the first of these eruptions is still posterior to this epoch of Nature. "It is evident," Mr. Brydone remarks, "that Ætna did not burn in the days of Homer, nor for a long time before, otherwise it would have been impossible that this poet should have talked so much of Sicily, without mentioning an object so astonishing." This remark of Mr. Brydone is extremely just; and, of course, the first known eruptions of Ætna should be dated after the age of Homer. But we perceive, from the poetical allusion of Pindar and Virgil, and from the descriptions of ancient and modern authors, that, in the space of eighteen or nineteen centuries, the whole face of this mountain and of the adjacent country has been changed by earthquakes, eruptions, torrents of lava, and the formation of hills and gulfs by these commotions, For the facts above related I am indebted to Mr. Brydone's excellent performance; and I have too high an esteem for Mr. Brydone to believe that he can be offended, because I do not agree with him as to the force of volcanos, and some other

conclusions he has drawn from these facts. No preceding author has observed with equal acuteness, or presented such lively pictures of the objects he surveyed; the whole republic of letters, therefore, ought to unite in celebrating a work so deserving of praise.

Torrents of glass in fusion, which have received the denomination of lavas, are not the first effects of eruptions. These eruptions are commonly announced by an earthquake more or less violent, which is the first effort of the subterraneous fire to escape from the bowels of the earth: it soon, however, opens a passage, which it enlarges by projecting rocks and every other obstruction to its motion. These materials, which are exploded to a great height, fall back upon each other, and form an eminence more or less considerable in proportion to the duration and violence of the eruption. As all the ejected matters are penetrated by fire, and most of them converted into burning ashes, the eminence to which they give rise is a mountain of solid fire, in which a great part of the matter is melted by the fervency of the heat. This melted matter soon begins to run, and generally flows to the foot of the new mountain by which it was produced. But, in small volcanos, which have not force sufficient to throw the ejected matters to a great distance, the lava issues from the top of the mountain. This effect is conspicuous in the eruptions of Vesuvius. The lava rises in the centre of the crater. The volcano first throws out stones and ashes, which fall perpendicularly

back into the old crater and augment its size. It is through this additional matter, which has fallen back, that the lava opens a passage. These two effects, though different in appearance, are nevertheless the same; for in a small volcano, which, like Vesuvius, has not force enough to give birth to new mountains by projecting its materials to a distance, the whole fall back upon the summit, and increase its height; and it is at the foot of this new crown of matter that the lava forces its way and flows down the mountain. This last effort is generally succeeded by a repose of the volcano. The succussions of the earth within, and the projections without, cease as soon as the lava flows. But the torrents of this glass in fusion produce effects still more extensive and disastrous than the convulsions of the mountain during an eruption. These rivers of fire ravage, destroy, and disfigure the surface of the earth. Nothing can oppose their dreadful progress. Of this the unfortunate inhabitants of Catania have had fatal experience. As their city had often been destroyed, either wholly or in part, by these torrents of lava, they built very strong walls of fifty-five feet in height. Surrounded by these ramparts, they believed themselves to be safe. The walls, it is true, resisted the heat and the weight of the torrent. But this resistance served only to dam up the lava, which rose above the ramparts, fell back upon the city, and ravaged every thing in its progress.

These torrents of lava are often half a league, and sometimes even two leagues broad.

"The last lava we crossed before our arrival at Catania, is of a vast extent. I thought we never should have done with it; it certainly is not less than six or seven miles broad, and appears in many places to be of an enormous depth.

"When we came near the sea, I was desirous to see what form it had assumed in meeting with the water. I went to examine it, and found it had driven back the waves for upwards of a mile, and had formed a large black high promontory, where before it was deep water. This lava, I imagined, from its barrenness, for it is as yet covered with a very scanty soil, had run from the mountain only a few ages ago; but was surprised to be informed, by Signior Recupero, the historiographer of Ætna, that this very lava is mentioned by Diodorus Siculus to have burst from Ætna in the time of the second Punic war, when Syracuse was besieged by the Romans. A detachment was sent from Taurominum to the relief of the besieged. They were stopped on their march by this stream of lava, which, having reached the sea before their arrival at the foot of the mountain, had cut off their passage; and obliged them to return by the back of Ætna, upwards of 100 miles about. His authority for this, he tells me, was taken from inscriptions on Roman monuments found on this lava, and that it was likewise well ascertained by many of the old Sicilian authors. Now, as this is about 2,000 years ago, one would have imagined, if lavas have a regular progress in becoming fertile

fields, that this must long ago have become at least arable; this, however, is not the case, and it is as yet only covered with a very scanty vegetation, and incapable of producing either corn or vines. There are indeed pretty large trees growing in the crevices, which are full of a rich earth; but in all probability it will be some hundred years yet, before there is enough of it to render this land of any use to the proprietors.

" We passed the river Alcantara on our way to Piedmonte, over a large bridge built entirely of lava; and near to this the bed of the river is continued for a great way, through one of the most remarkable, and probably one of the most ancient lavas that ever run from Ætna. In many places the current of the river, which is extremely rapid, has worn down the solid lava to the depth of fifty or sixty feet. Recupero, the gentleman I have mentioned, who is engaged in writing the Natural History of Ætna, tells me, he had examined this lava with great attention, and he thinks that its course, including all its windings, is not less than forty miles. It issued from a mountain on the north side of Ætna, and, finding some valleys that lay to the east, it took its course that way, interrupting the Alcantara in many places, and at last arrived at the sea, not far from the mouth of that river.

" The city of Jaci or Aci, and indeed all the towns on this coast, are founded on immense rocks of lava, heaped one above another, in some places to an amazing height; for it appears that

these flaming torrents, as soon as they arrived at the sea, were hardened into rock, which not yielding any longer to the pressure of the liquid fire behind, the melted matter continuing to accumulate, formed a dam of fire, which, in a short time, run over the solid front, pouring a second torrent into the ocean: this was immediately consolidated, and succeeded by a third, and so on . . . . The road from Jaci to this city is entirely over lava, and consequently very fatiguing and troublesome. Within a few miles of that place, we counted eight mountains formed by eruptions, with every one its crater, from whence the burnt matter was discharged. Some of these are very high, and of a great compass. It appears evidently, that the eruptions of Mount Ætna have formed the whole of this coast, and in many places have driven back the sea for several miles from its ancient boundary. . . . . . At Catania, near to a vault which is now thirty feet below ground, and has probably been a burial place, there is a draw-well, where there are several strata of lavas, with earth to a considerable thickness over the surface of each stratum. Recupero has made use of this as an argument to prove the great antiquity of the eruptions of this mountain. For if it requires two thousand years or upwards to form but a scanty soil on the surface of a lava, there must have been more than that space of time betwixt each of the eruptions which have formed these strata. But what shall we say of a pit they sunk near to Jaci,

of a great depth? They pierced through seven distinct lavas, one under the other, the surfaces of which were parallel, and most of them covered with a thick bed of rich earth. 'Now,' says he, 'the eruption which formed the lowest of these lavas, if we may be allowed to reason from analogy, must have flowed from the mountain at least 14,000 years ago.' . . .

"The great eruption of 1669, after shaking the whole country around for four months, and forming a very large mountain of stones and ashes, burst out about a mile above Monpelieri, and, descending like a torrent, bore directly against the middle of that mountain, and (they pretend) perforated it from side to side: this, however, I doubt, as it must have broken the regular form of the mountain, which is not the case. But certain it is, that it pierced it to a great depth. The lava then divided into two branches; and, surrounding this mountain, joined again on its south side; and, laying waste the whole country betwixt that and Catania, scaled the walls of that city, and poured its flaming torrent into the ocean. In its way, it is said to have destroyed the possessions of near 30,000 people, and reduced them to beggary. It formed several hills where there were formerly valleys, and filled up a large lake, of which there is not now the least vestige to be seen . . . There is no part of the coast from Catania to Syracuse nearer than thirty miles to its summit; and yet there has hardly been any great eruption, where the

lava has not reached the sea, and driven back its waters to a great distance, leaving high rocks and promontories, that for ever set its waves at defiance, and prescribe their utmost limits. What a tremendous scene must the meeting betwixt these adverse elements have formed!

"We may easily conceive the variety of changes this coast has undergone in the space of some thousands of years, as every great eruption must have made a considerable difference.—Virgil is wonderfully minute and exact in his geography of Sicily; and this is the only part of the island that seems to be materially altered since his time. He says there was a very large port at the foot of Ætna, where ships were secure from every wind;

'Portus ab accessu ventorum immotus et ingens;'

of which, at present, there are not the least remains. It is probably the same that was called by the Sicilians the port of Ulysses; which is often mentioned by their writers.—The place of its existence is still shown betwixt three and four miles up the country, amongst the lavas of Ætna. . . . . .

"The circumference of the great base of Ætna, Recupero told me, he had been at a good deal of pains to ascertain; as it had generally been computed only at 100 miles, or little more, although the radii of that circle had ever been esteemed at thirty of those miles; an absurdity in computation that had put him upon making this inquiry. The result was, that, taking the supposed distances of one place

from another all the way round, the sum of the whole amounted to 183 miles: an immense circle surely, and which is still enlarged by every considerable eruption."

Here we have a territory of about 300 superficial leagues, all covered or formed by the projections of volcanos. In this territory, independent of the peak of Ætna, there are many other mountains, all of which are furnished with craters, and exhibit an equal number of particular volcanos. Ætna, therefore, must not be regarded as a single volcano, but as an assemblage of volcanos, the greater part of which are extinguished, or burn with a gentle fire, and a few of them still act with violence. At present, the summit of Ætna throws out nothing but smoke; and there seems to have been no eruption from it for a very long period of time; because it is surrounded, to the distance of two leagues, with an equal surface, and below this high region, covered with snow, we find a large zone of vast forest, the soil of which is a fertile earth of several feet in thickness. This inferior zone is interspersed with inequalities, and presents heights, valleys, hills, and even pretty large mountains. But, as almost the whole of these inequalities are covered with a great thickness of earth, and as a long succession of time was necessary to convert volcanic matters into vegetable soil, we should regard the summit of Ætna, and the other mouths which surround it, to the distance of four or five leagues, as volcanos almost extinct, or, at least, stifled for a number of ages; for all the eruptions, the dates

of which can be ascertained for 2,500 years, have happened in the lower region, *i. e.* five, six, or seven leagues distant from the summit. The volcanos of Sicily seem to have had two different ages: the first very ancient, when the summit of Ætna began to act, and when the universal ocean left this summit dry, and sunk some hundreds of fathoms below: it was at this period that the first eruptions happened, which produced lava at the summit, and gave rise to those hills found below in the region of forests; but afterwards, the waters continuing to sink, they totally abandoned this mountain, as well as all the territories of Sicily and the adjacent continents. After this total retreat of the waters, the Mediterranean was only a lake of a moderate extent, and its waters were very distant from Sicily, and all the countries whose coasts it now washes. During all this time, which lasted several thousand years, Sicily was perfectly tranquil: Ætna, and the other ancient volcanos which surround its summit, had ceased to act; and it was not till after the augmentation of the Mediterranean by the waters of the ocean and of the Black Sea, *i. e.* after the rupture of the straits of Gibraltar and of the Bosphorus, that the waters attacked the bases of the new mountains of Ætna, and produced those modern eruptions, which have happened since the age of Pindar to the present time; for this poet is the first author who has taken notice of eruptions of volcanos in Sicily. Vesuvius was precisely in the same situation: it was long one of the extinguished vol-

canos of Italy, which are very numerous; and their eruptions were not renewed till after the waters of the Mediterranean were increased, and reached the bases of these inflammable mountains. The memory of the first eruptions, and even of all those which preceded the age of Pliny, was entirely obliterated. Neither should this circumstance excite surprise; for ten thousand years have perhaps elapsed since the general retreat of the waters to the augmentation of the Mediterranean, and an equal portion of time from the first eruption of Vesuvius till their removal. All these considerations seem to prove, that subterraneous fires cannot act with violence, unless when they are so near the sea as to receive a shock from a great body of water. This reasoning is confirmed by other phænomena: volcanos sometimes throw out great quantities of water, and likewise torrents of bitumen. P. de la Torré, an able philosopher, relates, "that, on the 10th of March, 1755, an immense torrent of water issued from the foot of the mountain, which deluged the neighbouring country. This torrent brought down such a quantity of sand, that it covered an extensive plain. These waters were very hot. The stones and sand left on the plain differed not from those found in the sea. The torrent of water was immediately followed by another of inflamed matter, which proceeded from the same opening *."

* Hist. du Mont Vesuve, par le P. J. M. de la Torré; Journal Etranger, mois Janvier, 1576, p. 203.

"The same eruption, 1755, was preceded," says M. d'Arthenay, "by an inflammation so great, that it illuminated more than twenty-four miles of country along the coast of Catania. The explosions were soon so frequent, that, on the 3d of March, we perceived a new mountain in the top of the old summit, in the same manner as lately happened to Vesuvius. Lastly, the magistrates of Mascali informed us, that, on the 9th of the same month, the explosions were terrible; that the whole sky was darkened with smoke; that, on the approach of night, it began to rain a deluge of small stones, some of which weighed three ounces, and covered all the adjacent cantons; that this tremendous rain continued an hour and a quarter, and was succeeded by another of black ashes, which lasted the whole night; that next day, about eight o'clock in the morning, the summit of Ætna threw out a river of water, which, for magnitude, might be compared to the Nile; that the most ancient and rugged mountains of lava were in an instant converted by this torrent into a vast plain of sand; that the water, which fortunately ran not above half a quarter of an hour, was very hot; that the stones and sand carried along with it differed not from those of the sea; that, after this inundation, there issued from the same mouth a small rivulet of fire, which flowed during twenty-four hours; that, on the 11th, about a mile below this mouth, a rent happened, through which issued a stream of lava, of about a hundred fathoms broad by

two miles in length, and that it continued its course through the country the same day in which M. d'Arthenay wrote this relation *."

Let us attend to what Mr. Brydone has remarked concerning this eruption: "Part of the fine forests which compose the second region of Ætna was destroyed by a very singular event, not later than the year 1755. During an eruption of the volcano, an immense torrent of boiling water issued, as is imagined, from the great crater of the mountain, and in an instant poured down to its base; overwhelming and ruining every thing it met with in its course. Our conductors showed us the traces of this torrent, which are still very visible; but are now beginning to recover verdure and vegetation, which for some time appeared to have been lost. The track it has left seems to be about a mile and a half broad; and in some places still more.

"The common opinion, I find, is, that this water was raised by the power of suction, through some communication betwixt the volcano and the sea; the absurdity of which is too glaring to need a refutation. The power of suction alone, even supposing a perfect vacuum, could never raise water to more than thirty-three or thirty-four feet, which is equal to the weight of a column of air the whole height of the atmosphere."

I must here observe, that Mr. Brydone seems

* Mem. des Savans Etrangers, imprimés comme suite des Mem. l'Acad. des Sciences, tom. iv. p. 147.

to have deceived himself; for he confounds the force arising from the weight of the atmosphere with the force of suction produced by the action of fire. The force of the air, when a vacuum is made, is indeed limited to thirty-four feet. But the force of suction by fire has no limits: it is always proportioned to the quantity and intensity of the heat by which it is produced, as is evident from the common effects of blast furnaces. Hence the opinion of the *enlightened people of the country*, instead of being absurd, seems to be well founded. It is necessary that the cavities of volcanos should communicate with the sea: without this communication, such immense torrents of water could not be thrown out, nor indeed could any eruption ever happen; for no power, except the shock produced by the mingling of fire and water, could give rise to such violent effects.

The volcano of Pacayita, called the water volcano by the Spaniards, in all its eruptions, throws out torrents of water. The last eruption, in the year 1773, destroyed the city of Guatimala, and the torrents of water and lava descended to the South Sea.

With regard to Vesuvius, it has been remarked, "that a wind, which blows from the sea, penetrates into the mountain. The noise it makes in certain cavities is heard, as if some torrent passed below: this noise ceases whenever the land winds blow, and, at the same time, the exhalations from the mouth of Vesuvius become less considerable. But, when the wind

blows from the sea, this noise, which resembles that of a torrent, recommences, and the exhalations of flame and smoke increase. The water of the sea, by thus insinuating itself into the mountain, sometimes in greater, and sometimes in smaller quantities, is the reason why this volcano has often thrown out both ashes and water *."

The learned M. d'Arthenay, who has compared the modern with the ancient state of Vesuvius, relates, "that, during the interval which preceded the eruption 1631, the funnel or crater of the mountain was covered with trees and verdure; that the small plain which bounds it produced excellent pasture; that, in departing from the superior margin of the crater, we have a mile to descend before we arrive at this plain, in the middle of which was another gulf. We descended this gulf about a mile, by narrow and winding roads of an equal declivity, which led into a vast space surrounded with caverns, from whence there issued *winds so impetuous and so cold, that it was impossible to endure them.*" According to the same observer, the summit of Vesuvius was then five miles in circumference. We should not therefore be surprised, that some philosophers have maintained that what seems now to be two mountains, was formerly one; that the volcano was in the centre, but that the south side, having fallen by the force of some

* Descript. Historique et Philos. de Vesuve, par. M. l'Abbé Mecatti; Journal Etranger, mois Oct. 1754.

eruption, produced the valley which separates Vesuvius from Mount Somma *.

M. Steller remarks, "that the volcanos in the north of Asia are almost always isolated; that they have nearly the same surface; and that there are always lakes on the summits, and hot waters at the foot of those mountains whose volcanos are extinct. This," he adds, "is a farther proof of the correspondence established by nature between the sea, mountains, volcanos, and hot waters." We find many springs of hot water in different parts of Kamptschatka †. In the island of Sjanw, forty leagues distant from Ternate, there is a volcano, which often throws out water, ashes ‡, &c. But it is unnecessary to accumulate more facts to prove the communication of volcanos with the sea. The violence of their eruptions would be sufficient to justify the presumption; and the general fact, that all acting volcanos are situated near the sea, completes the demonstration. However, as some philosophers have denied the reality and even the possibility of this communication of volcanos with the sea, I shall mention another fact, related by M. de la Condamine, a man equally enlightened as worthy of credit. "On the 14th of June, 1755," he remarks, "I mounted to the summit of Vesuvius, and even to the brink of the funnel formed

* Observ. sur le Vesuve, par M. d'Arthenay; Journal de Savans Etrangers, tom. iv. p. 147.

† Hist. Gen. des Voyages, tom. xix. p. 238.

‡ Ibid. tom. xvii. p. 54.

round the mouth of the volcano by its last explosion; and I perceived in the gulf, about forty fathoms deep, a great cavity resembling a vault toward the north of the mountain. I threw down large stones into this cavity, and counted twelve seconds before the noise of their rolling ceased. At the end of their fall I heard a noise similar to that of a stone falling into a mire; and, when nothing was thrown in, I heard a noise like that of agitated waves *." If the fall of the stones had been perpendicular, and met with no obstacle, twelve seconds would have given a depth of 2,160 feet, and the bottom of the gulf would, on this supposition, be deeper than the level of the sea; for, according to le P. de la Torré, in 1753, this mountain was only 1,677 feet above the surface of the sea, and this elevation has been diminished since that period. Hence we may conclude, that the caverns of this volcano descend below the level of the sea, and, of course, they may have subterraneous communications.

On the 15th of July, 1753, I received, from an eye-witness, and an accurate observer, a distinct detail of the then condition of Vesuvius. I shall subjoin it in the words of the author, because it will tend to fix our ideas concerning what is to be farther apprehended from the effects of this volcano, the force of which seems to be greatly diminished.

" Having arrived at the foot of the mountain,

* Voyage en Italie, par M. de la Condamine; Mem. de l'Acad. des Sciences, ann. 1757, p. 371.

which is about two leagues distant from Naples, we mounted during an hour and a half upon asses, and an equal portion of time was employed in completing the journey on foot. This is the steepest and most fatiguing part of the way. We held by the belts of two men who went before, and we climbed among ashes and stones formerly exploded.

"In our ascent, we saw the lavas of different eruptions. The most ancient, whose age is uncertain, but tradition assigns it 200 years, is of an iron-gray colour, and has all the appearance of a stone: it is used for paving the streets of Naples, and in other works of masonry. We found others, which were said to be sixty, forty, and twenty years old. The last was thrown out in the year 1752 . . . . These different lavas, except the most ancient, when viewed at a distance, have the appearance of a blackish brown rugged earth, more or less recently laboured. When viewed nearer, it is a matter perfectly similar to the refuse of iron foundries. It is more or less composed of earth and ferruginous matter, and approaches more or less to the nature of stone.

"When arrived at the top, which, before the eruption, was solid, we find the first basin, whose circumference is said to be two Italian miles, and its depth appears to be about forty feet. It is surrounded with a crust of earth, which gradually thickens toward the base, and its upper margin is two feet broad. The bottom of this basin is covered with a greenish yellow sulphureous matter,

which is hard and warm, but does not burn; and smoke issues through different fissures.

"In the centre of this basin we see a second, which is about half the circumference and half the depth of the former. Its bottom is covered with a blackish brown matter, similar to the freshest lavas we find on the road.

"In the second basin, there is a small mount which is hollow internally, open at the top, and likewise open from the top to the base toward that side of the mountain where we ascended. This lateral opening is about twenty feet broad at the top, and four feet at the base. The height of this small mount is about forty feet; the diameter of the base is about as much, and that of the opening at the top about twenty feet.

"This base rises about twenty feet above the second basin, and forms a third basin, which is filled with a liquid and burning matter, and has a perfect resemblance to the melted metal in an iron furnace. This matter perpetually boils with great violence. Its movements have the appearance of a lake moderately agitated, and the noise it produces is similar to that of waves.

"Every minute, quantities of this matter are projected into the air, like water thrown up by many jets-d'eaux. These projections produce the appearance of burning sheafs of wheat, which rise to the height of thirty or forty feet, and fall back in various curves, partly into their own basin, and partly the second, which is

covered with a black matter. It is the reflected light of these burning jets which is seen from Naples during the night. The noise they make in their elevation and fall seems to be composed of that of fire-works, and the noise produced by the waves of the sea, when violently dashed against a rock.

"The boilings and jets produce a perpetual evacuation of this matter. Through the aperture of four feet, at the base of the small mount, a burning rivulet, of the same dimensions with the aperture, continually flows, and descends in an inclined canal, and with a mean movement, into the second basin, where, after dividing into several rills, it stops and is extinguished.

"This burning rivulet consists of fresh lava, which runs only eight days. But, if it continues to augment, it will in time produce a new overflowing into the plain, similar to that which happened two years ago. The whole is accompanied with a thick smoke, which has not the odour of sulphur, but precisely that which proceeds from a furnace where tiles are roasted.

"We may, without danger, go round the margin of the crater; because the little hollow mount, from which the burning projections are made, is sufficiently distant to prevent all apprehensions. We may also, without danger, descend into the first basin; we may even go upon the margin of the second, if the reverberation of the burning matter does not prevent us.

" This was the real state of Vesuvius on the 15th of July, 1753. But it perpetually changes its form and aspect. It now throws out no stones, and we perceive no flame*."

These observations seem to prove, that the seat of the burning in this volcano, and perhaps in all others, is at no great depth in the bowels of the mountain, and that it is not necessary to suppose their fires on a level with, or lower than the sea, and to make their explosions from thence during the time of eruptions. It is sufficient that there are caverns and perpendicular fissures below, or rather at the side of the fire, which serve as ventilators to the furnace of the volcano.

M. de la Condamine, who has had more opportunities than any other philosopher, of examining a number of volcanos in the Cordeliers, has likewise explored that of Vesuvius, and all the adjacent territories.

" In the month of June, 1755," he remarks, " the summit of Vesuvius formed an open funnel in a mass of ashes, calcarious stones, and sulphur, which burned at different distances, and tinged the surface with its colour. The fire streamed through different crevices, in which the heat was so great, that, in a short time, it inflamed a stick thrust some feet down these fissures.

" For several years past, the eruptions of this

* Note sent to M. de Buffon from Naples, in September, 1753.

volcano have been frequent; and, every time flames and liquid matter were thrown out, the mountain underwent considerable changes both in its height and external figure. . . . . In a small plain on the side of the mountain, composed of ashes and stones projected from the volcano, there is a breast of steep semicircular rocks, of 200 feet high, which bound this plain on the north. We perceived, near the crevices recently opened in the flanks of the mountain, the places through which the torrents of lava, with which the whole of this valley is filled, had issued during the last eruption.

"This spectacle presents the appearance of metallic waves cooled and congealed. We may form an imperfect idea of it by imagining a sea of thick and tenacious matter, the waves of which had begun to calm. This sea has its islands; they are detached masses, like hollow spongy rocks, whimsically interspersed with vaults and grottos, under which the burning liquid had made a kind of reservoirs, resembling furnaces. From these grottos, with their vaults and pillars, hang numbers of scoriæ, in the form of irregular grapes, of all shades and colours. . . . . .

"All the mountains and coasts in the environs of Naples, are nothing but masses of burnt matter thrown out by volcanos which now no longer exist, and whose eruptions, which have been anterior to all history, probably formed the ports of Naples and Puzzoli. The same

matters are conspicuous on the whole road from Naples to Rome, and even at the port of Rome itself.

" The whole interior part of Mount Frascati, the chain of hills which extends from this place to Grotta-ferrata, Castlegandolfo, and as far as Lake Albano, a great part of Mounts Tivoli, Caprarola, Viterbe, &c., are composed of calcined stones, of pure ashes, of scoriæ, of matter similar to the dross of iron and burnt earth, and of real lava; lastly, the whole matters resemble those of which the soil of Portici is composed, and which have issued from the sides of Vesuvius in so many different forms. . . . . . Hence we must necessarily conclude, that all this part of Italy has been overturned by volcanos. . . . . . .

" Lake Albano, whose margins are interspersed with calcined matters, is nothing but the mouth of an ancient volcano. . . . . The chain of Italian volcanos extends as far as Sicily, and still exhibits a number of fires under different forms; in Tuscany, we have the exhalations of Firenzuola, and the warm waters of Pisa; in the Ecclesiastic State, those of Viterbe, of Norcia, of Nocera, &c.; in the kingdom of Naples, those of Ischia, Solfatara, and Vesuvius; in Sicily and the islands adjacent to Ætna, the volcanos of Lipari, Stromboli, &c. The other volcanos of this chain have been extinct from time immemorial, and have left such relics, as, though they do not always strike us at first sight, fail

not to be recognisable on an attentive examination*."

"It is very probable," says M. l'Abbé Mecati, "that, in past ages, the kingdom of Naples, besides Vesuvius, was infested with several other volcanos."

"Mount Vesuvius," le P. de la Torré remarks, "seems to be a portion detached from that chain of mountains which, under the name of Appennines, divides all Italy through its whole length. . . . . . This volcano is composed of three different mountains: one of them Vesuvius, properly so called; the other two are Mounts Somma and Otajano. The two last are situated toward the west, and form a kind of semicircle round Vesuvius, with which they have a common base.

"This mountain was formerly surrounded with fertile fields, and itself covered with trees and verdure, except the summit, which was flat and sterile, and where several open caverns were to be seen. The top was surrounded with rocks, which rendered it of difficult access. These rocks were so high, that they concealed the valley between Vesuvius and Mounts Somma and Otajano. The summit of Vesuvius, which has since sunk considerably, being then much more remarkable, it is not surprising that the ancients believed it had only one top. . . . .

"The breadth of the valley is 2,220 Paris feet, and its length nearly the same. . . . . .

* Voyage en Italie, par M. de la Condamine; Acad. des Sciences, ann. 1757, p. 371—379.

It invests one half of Vesuvius, and, like all the sides of the mountain, it is covered with burnt sand and small pumice stones. The rocks on Mounts Somma and Otajano exhibit a few herbs, and the surface of these mountains is covered with trees and verdure. These rocks, at first sight, have the appearance of burnt stones; but, on a closer examination, they are, like the rocks of other mountains, composed of strata of natural stones, of a chesnut-coloured earth, of chalk, and of white stones, which have not the smallest appearance of having been liquified by fire. . . .

"Round Vesuvius we see openings which have been made at different times, and through which lavas had issued. These torrents of burning matter, which sometimes come from the sides, and sometimes from the top of the mountain, descend into the plains, and sometimes run as far as the sea, and harden like a stone when the matter cools. . . .

"On the summit of Vesuvius there is only a small margin of four or five palms wide, which describes a circumference of 5,624 Paris feet. Upon this margin we can walk pretty commodiously. The whole of it is covered with burnt sand, under which we find stones partly natural and partly calcined. . . . . In two elevations on this margin, we find beds of natural stones arranged in the same manner as in other mountains; which confutes the notion of those who regard Vesuvius as a mountain gradually raised above the plain of the valley. . . . .

"The depth of the gulf where the matter boils

is about 543 feet; and the height of the mountain above the level of the sea is 1,677 feet, which is one third of an Italian mile.

"This height has been more considerable. The eruptions which have changed the external form of the mountain, have likewise diminished its elevation; for the parts they detached from the summit rolled into the gulf*."

From all these examples, if we consider the external figure of Sicily and other countries ravaged by fire, we shall evidently perceive that no volcano exists which is purely isolated or detached. The surface of these countries every where presents a succession, and sometimes groups of volcanos. This we have already seen with regard to Ætna, and shall give a second example of it in Hecla. A great part of the island, like Sicily, is only a group of volcanos, which I shall prove by the following observations:

The whole island ought to be regarded as a vast mountain interspersed with deep cavities, concealing in its bowels great quantities of minerals, vitrified and bituminous substances, and rising from the midst of the sea in the form of a short flattened cone. Its surface presents to the eye nothing but tops of mountains covered with snow and ice; and lower down we have the picture of confusion and ruin. It is an enormous mass of stones and fragments of rocks, which are sometimes porous and half calcined, and exhibit a

* Hist. du Mont Vesuve, par le P. de la Torré; Journal Etranger, Janvier, 1756, p. 182—208.

hideous appearance by their blackness and the marks of fire impressed upon them. The fissures and hollows of rocks are filled with a red, and sometimes with a black or white sand: but, in the valleys between the mountains, we find agreeable plains *.

Most of Jokuts, which are mountains of a middle height, and overtopped by others of a greater elevation, are volcanos, that occasionally throw out flames, and produce earthquakes: of these there are no less than twenty in this island. The inhabitants in the neighbourhood of these mountains have learned, by experience and observation, that, when the ice and snow rise to a considerable height, and stop the mouths of these cavities, which formerly discharged flames, earthquakes are about to happen, which are always succeeded by eruptions of fire. It is for this reason that the Icelanders are at present afraid lest the Jokuts, which, in the year 1728, threw out flames in the canton of Skaftfield, should soon be again inflamed; the ice and snow being accumulated on their summits, and appearing to obstruct those vents which favoured the exhalations of the subterraneous fires.

In 1721, the Jokut called Koëtlegan, about five or six leagues to the west of the sea, near the bay of Portland, broke out into flames, after several succussions of the earth. This conflagration melted masses of ice of an enormous thickness, and gave rise to impetuous torrents, which de-

* Introd. a l'Hist du Danemark.

luged the country, and carried down to the sea prodigious quantities of earth, sand, and stones. The solid masses of ice, and the immense quantity of earth, stones, and sand, transported by the inundation, so loaded the sea, that, at half a mile from the coast, a small mountain was formed, which still appeared above the sea in the year 1750. We may form some idea of the quantity of matter carried down to the sea by this inundation, when we consider that it was obliged to retreat twelve miles beyond its former limits.

The inundation continued three days; and it was not till after this period that a person could pass on foot to the mountains. . . . .

Hecla, which has always been regarded as one of the most famous volcanos in the universe, on account of its tremendous eruptions, is now one of the least dangerous in the island. Mounts Koëtlegan and Krafle have recently made as great ravages as Hecla did of old. It has been remarked, that this last volcano has thrown out flames ten times only in the space of 800 years, namely, in the years 1104, 1157, 1222, 1300, 1341, 1362, 1389, 1558, 1636, and, lastly, in the year 1693. This eruption commenced on the 13th of February, and continued to the month of August following. All the other eruptions lasted a few months only. From the above dates it appears, that Hecla made its greatest ravages in the fourteenth century, having undergone no less than four eruptions; that it remained perfectly tranquil during the fifteenth century; and that it

threw out no fire for 160 years. From this period, there was one eruption only in the sixteenth, and two in the seventeenth century. We now perceive in this volcano neither fire, nor smoke, nor exhalations of any kind. We only find, in some small hollows, as is common in many other parts of the island, boiling water, stones, sand, and ashes.

In 1726, after a few succussions of the earth, which were felt only in the northern cantons, Mount Krafle began to throw out, with a dreadful noise, smoke, flames, ashes, and stones. This eruption continued two or three years, without doing any damage; because the whole rejected matter fell back upon the mountain, or round its base.

In 1728, the fire communicated with some mountains situated near Krafle, which burnt during several weeks. When the minerals they contained were melted, a river of fire ran gently toward the south into the country below these mountains. This river threw itself into a lake about three leagues from Mount Krafle, and, by the shock of the water, produced a horrible noise, and clouds of vapours. The running of the lava did not cease till 1729, when the matter which formed it was probably exhausted. The lake was filled with an immense quantity of calcined stones, which raised its water considerably. It is about twenty leagues in circumference, and situated at an equal distance from the sea. We shall not take notice of the other

volcanos in this island; it is sufficient that we have mentioned the most considerable of them *.

From this description we perceive that the Jokuts of Hecla greatly resemble the secondary volcanos of Ætna: that, in both, the highest summit is tranquil; that the summit of Vesuvius is much sunk; and that probably those of Ætna and Hecla were formerly higher than they are at present.

Though the topography of volcanos in other parts of the world is not so well known as that of those in Europe, we may, nevertheless, presume, from analogy, and the similarity of their effects, that they resemble each other in every respect. They are all situated in islands, or upon the coasts of continents. Almost the whole of them are surrounded with secondary volcanos. Some of them are active, and others extinguished or quiet. The number of the latter is greater, even in the Cordeliers, which appear to be the most ancient domain of volcanos. In the south of Asia, the islands of Sonde, the Moluccas, and Philippines, bear evident marks of destruction by fire, and are still infested with volcanos. They are likewise very frequent in the island of Japan: this country is also more subject to earthquakes than any other part of the globe. In many places of Japan there are hot fountains. Most of the Indian islands, and all the seas of these eastern regions, present to our eyes nothing but peaks and detached sum-

* Hist. Gen. des Voyages, tom. xviii. p. 9—11.

mits, which vomit out fire, and deep indented coasts, the relics of ancient continents which are now no more. Here the mariner often meets with ports which daily sink; and even whole islands have been known to disappear, and to be swallowed up, with their volcanos, by the waters. The seas in China are warm, which is a proof that there is a great effervescence in the maritime basins of this region. The hurricanes are tremendous, and water spouts are frequent. The tempests are always preceded by general and perceptible boilings of the waters, and by various meteors and other exhalations, with which the atmosphere is loaded.

The volcano of Teneriffe has been explored by Dr. Thomas Heberden, who resided several years in the village of Oratava, which is situated at the foot of the Peak. In his way, he found large stones disposed on all sides at several leagues from the top of the mountain. Some of them appeared to be entire, and others seemed to have been burnt, and thrown to this distance by the volcano. In ascending the mountain, he still saw burnt rocks scattered about in large masses.

" We arrived," Dr. Heberden remarks, " at the famous grotto of Zegds, which is surrounded on all sides with enormous masses of burnt rocks. . . .

" A quarter of a league higher, we met with a sandy plain, in the middle of which there is a pyramid of sand or yellowish ashes, called

the Sugar Loaf. Round its base, fuliginous vapours perpetually arise. From thence to the summit, the distance might be half a quarter of a league. But the ascent is too difficult on account of its steepness and the bad footing. . . .

"However, we reached what is called the Cauldron, which is twelve or fifteen feet deep. Its sides taper to the bottom, and form a cavity, which resembles a reversed cone. . . . Here the ground is very warm; and, from about twenty tubes or chimneys, a thick sulphureous vapour arises. The whole ground seems to be mixed with sulphur, which gives the surface a brilliant appearance. . . .

"Upon almost all the stones in the neighbourhood, we perceive a greenish colour, intermixed with yellow, like gold. A small part of this sugar loaf is as white as chalk, and another part, still lower, resembles red clay covered with salt. . . .

"In the middle of another rock we discovered a hole, which exceeded not two inches in diameter, from whence proceeded a noise similar to that of a considerable quantity of water boiling over a great fire *."

The Azores, the Canaries, the islands of Cape Verd, Ascension Island, and the Antilles, which appear to be the relics of ancient continents that united the Old Continent with America, offer nothing to our observation but burnt lands, or lands which still continue to burn. The vol-

* Observations on the Peak of Teneriffe by Dr. Heberden.

canos formerly sunk under the waters with the countries which supported them, excite such terrible tempests, that, in one of these storms, which happened at the Azores, the suet fixed to the end of the plumb-line melted by the heat at the bottom of the sea.

In Asia, and particularly in the islands of the Indian Ocean, volcanos are numerous. One of the most famous is Mount Albours, near Mount Taurus, about eight leagues from Herat. The top of this mountain sends forth a perpetual smoke; and it frequently throws out flames and burning matter in such quantities as to cover all the adjacent plains with ashes. In the island of Ternate, there is a volcano which discharges matter similar to pumice stones. Some voyagers allege, that this volcano is most furious during the equinoxes, because these periods are attended with certain winds which increase the inflammation of those fires that have continued to burn for ages *. The island of Ternate is not above seven leagues round, and is only the top of a large mountain. The land rises from the coast to the middle of the island, where the volcano mounts to a height so great, that it is difficult to climb to its top. Several rills of sweet water descend from the sides of the mountain; and, when the air is calm, and the weather fine, this burning gulf is less agitated than during storms and high winds †. This is a confirmation of what

* See Voyages d'Argensola, tom. i. p. 21.

† See Voyage de Schouten.

I formerly remarked, and seems to prove, that the fire of volcanos proceeds not from a great depth, but from the top or higher parts of the mountain; for, if it were otherwise, high winds could not increase the violence of the flames.

There are other volcanos in the Molucca islands. In one of the islands of Mauritius, about seventy leagues from the Moluccas, there is a volcano, the effects of which are equally violent as those of the mountain at Ternate. The island of Sorca, one of the Moluccas, was formerly inhabited. In the middle of this island there is a very high mountain, with a volcano at its summit. In 1693, this volcano discharged an immense quantity of bitumen and inflamed matter, which, after forming a burning lake, gradually extended till it covered the whole island *.

There are several volcanos in Japan, and the adjacent islands, which send out flames in the night, and smoke in the day. In the Philippine islands, there are likewise several burning mountains. One of the most remarkable, and, at the same time, the most recent volcano in the Indian islands, is that near the town of Penarucan in the island of Java. It commenced in the year 1586, and, at the first eruption, it threw out immense quantities of sulphur, bitumen, and stones. The same year, Mount Gounapi, in the island of Banda, which had been a volcano about seventeen years only, opened and ejected, with a dreadful noise, rocks, and matter of every

* See Phil. Trans. abridg. vol. ii. p. 391.

kind. There are still other volcanos in India, as in Sumatra, and in the north of Asia, beyond the river Jenisca, and the river Pesida: but the two last are little known.

Near Fez in Africa, there is a mountain, or rather a cavern, called Beni-guazeval, which constantly throws out smoke, and sometimes flame. One of the Cape de Verd islands, called the island of Fuogo, is nothing but a huge mountain, which burns incessantly. This volcano throws out stones and ashes; and the Portuguese, who often attempted to inhabit the island, have always abandoned the project, on account of the volcano. The Peak of Teneriffe, which is reckoned one of the highest mountains in the world, throws out fire, ashes, and large stones. From the top of it, rivulets of melted sulphur run down the south side across the snows. This sulphur soon condenses, and forms veins in the snow, which are distinguishable at great distances.

America, and particularly the mountains of Mexico and Peru, are much infested with volcanos: that of Arequipa is one of the most celebrated: it often produces great earthquakes, which are more frequent in Peru than in any country of the world. Next to Arequipa, the volcanos of Carrappa and Malahallo are, according to the relation of travellers, the most considerable. But there are many others in the New World of which we have no knowledge. M. Bouguer, in his voyage to Peru, published in the Memoirs of the Academy for the year 1744, mentions two volcanos, the one called Cotopaxi,

and the other Pichincha. The first is at some distance from, and the other very near, the town of Quito. In the year 1742, he saw an eruption of Cotopaxi, which, at that time, burst open a new mouth in the mountain. It did no other damage than that of melting the snow, and producing such torrents, as, in three hours, laid the whole country, to the extent of eighteen leagues, under water, and overturned every thing in their course.

Popochampeche and Popocatapec are the chief volcanos in Mexico. It was near this last that Cortes passed in his way to the city of Mexico: some of the Spaniards ascended to the top of the mountain, where they found the crater to be about half a league in circumference. Sulphureous mountains have also been found in Guadaloupe, Tercera, and in others of the Azore islands; and, if all the mountains from which smoke or flames issue were to be considered as volcanos, their number would exceed sixty. We have only mentioned those which are so formidable, as, by their frequent eruptions, to prevent people from living near them.

The numerous volcanos in the Cordeliers, as I formerly remarked, produce almost perpetual earthquakes, which prevent the inhabitants from building with stone any higher than the first floor; and the upper parts of their houses, for the same reason, are constructed with rushes or very light wood. In these mountains there are also many precipices and large gulfs, the walls of which are black and burnt: they are similar to

the precipice of Mount Ararat in Armenia, called the Abyss, and are the craters of extinguished volcanos.

A late earthquake at Lima was attended with the most dreadful effects. The town of Lima, and the port of Callao, were almost entirely swallowed up. But the mischief was still more terrible at Callao. The sea rose and covered every house in that unfortunate town, and drowned the whole inhabitants, leaving only a single tower as a monument of its devastations. Of twenty-five vessels which lay in the harbour, four were driven a league upon land, and the rest were swallowed up by the waves. Of Lima, which was a very large city, only twenty-seven houses remained standing. Multitudes of people perished; and the disaster was particularly fatal to the monks and other religious, because their buildings were lofty and of more solid materials than the common houses. This calamity happened in the month of October, 1746, during the night; and the succussion lasted fifteen minutes.

Near the port of Pisca, in Peru, there was formerly a famous city, situated on the sea-coast; but, on the 19th of October, 1682, it was almost entirely destroyed by an earthquake; for the sea, having exceeded its usual limits, sweeped away this unfortunate city, with all its inhabitants.

By consulting historians and travellers, we shall find many accounts of earthquakes and eruptions of volcanos, equally dreadful and destructive as those we have mentioned. Pesi-

donius, quoted by Strabo *, relates, that a city of Phœnicia, near Sidon, was swallowed up by an earthquake, with the neighbouring territory, and two thirds of Sidon itself; that this effect was not produced so suddenly as to prevent the inhabitants from escaping by flight; that it extended over most of Syria, and as far as the Cyclades islands and Eubœa, where the fountains of Arethusa suddenly stopped, and appeared a few days afterwards by new sources, at a considerable distance from the old; and that the earthquake continued to shake the island, sometimes in one place, and sometimes in another, till the earth opened in the valley of Lepanta, and discharged a great quantity of burning matter. Pliny informs us †, that, in the reign of Tiberius, twelve cities in Asia were overturned; and he mentions ‡, in the following terms, a prodigy occasioned by a violent earthquake. "Factum est semel (quod equidem in Etruscæ disciplinæ voluminibus inveni) ingens terrarum portentum, Lucio Marco, Sex. Julio Coss. in agro Mutinensi. Namque montes duo inter se concurrerunt, crepitu maximo adsultantes recedentesque, intor eos flamma, fumoque in cœlum exeunte interdiu, spectante e via Æmilia magna equitum Romanorum familiarumque et viatorum multitudine. Eo concursu villæ omnes elisæ, animalia permulta, quæ intra fuerunt, exanimata sunt," &c. St. Augustin tells

* Lib. i. † Lib. i. c. 84. ‡ Lib. ii. c. 83.

us *, that, in Lybia, 100 towns were destroyed by an earthquake. In the time of Trajan, the earth opened and devoured the city of Antioch, and a great part of the adjacent country. It was again destroyed by the same cause during the reign of Justinian, in the year 528, and 40,000 of its inhabitants perished. It was visited with a third earthquake in the days of St. Gregory, sixty years after the former, which destroyed no less than 60,000 of its inhabitants. In the reign of Saladin, *anno* 1182, most of the cities of Syria and of Judæa were laid waste by the same calamity. Earthquakes have been more frequent in Apulia and Calabria than in any other part of Europe. In the time of Pope Pius II, all the churches and palaces of Naples were thrown down, and about 30,000 lives were lost: those who escaped were obliged to live in tents till houses were built for them. In 1629, 7,000 persons perished in Apulia by earthquakes; and, in 1638, the city of Saint Euphemia was swallowed up, and left behind it nothing but a stinking lake: at the same time, Ragusa and Smyrna were almost totally destroyed. In 1692, an earthquake was felt in Britain, Holland, Flanders, Germany, and France: it was most severe along the coasts of the sea, and near great rivers. It agitated at least 2,600 square leagues, though it lasted but two minutes. The commotion was greater in the mountains than in the val-

* Lib. ii. de Miraculis, c. 3.

leys*. On the 10th of July, 1688, there was an earthquake at Smyrna, which began with a motion from west to east. The castle was first overturned; its four walls separated from each other, and sunk six feet in the sea. This castle stood formerly on an isthmus, which is now a real island, about 100 paces from the land. The east and west walls fell; but the north and south walls still remain. The city, which is near ten miles from the castle, was overthrown soon after. The earth opened in many places, attended with subterraneous noises; and five or six dreadful shocks were felt before the approach of night, the last of which lasted about half a minute. The ships in the roads were greatly agitated; the ground on which the town stood sunk two feet; and not above a fourth of the houses withstood the concussion, and those were mostly founded on rock. From fifteen to twenty thousand lives were lost †. In 1695, an earthquake was felt at Bologna in Italy; and it was remarked, as a singular phænomenon, that the sea was much troubled the day preceding ‡.

"On the 4th of May, 1614, a terrible earthquake happened at Tercera, which, beside private houses, overturned eleven churches and nine chapels in the city of Angra; and the city of Praya was so much shaken, that hardly a house was left standing: and, on the 15th of June, 1628, the island of St. Michael was visited with

* See Ray's Discourses, p. 272.

† See l'Hist. de l'Acad. des Sciences, ann. 1688.

‡ Ibid. ann. 1696.

a great earthquake. Near this island, in the open sea, there arose a new island in a place where the water was 150 fathoms deep. This island was more than a league and a half long, and above six fathoms high *.

" In the island of St. Michael, another earthquake began on the 26th of July, 1691, and continued to the 12th of the following month. Tercera and Fayal were shaken next day with such violence, that they seemed to turn about. These concussions, however, were repeated there only four times; but, at St. Michael, they ceased not a moment during the space of eleven days. The islanders abandoned their houses, which every where tumbled down before their eyes, and remained the whole time in the open fields, exposed to the injuries of the weather. The whole town of Villa Franca was overturned to the foundation, and most of the inhabitants were buried under its ruins. In several places, the plains were elevated into hills, and, in others, the hills sunk down into valleys. A fountain of fresh water issued from the ground, and ran for four days, and then stopped all of a sudden. The air and the sea were in such commotion, that they made a noise resembling the bellowings of ferocious animals. Many people died of fear. There was not a vessel in the harbours which was not agitated in a dangerous manner; and those which lay at anchor, or were under sail, at the distance of twenty leagues, were still more se-

* See Mandelslo's Voyages.

verely tossed. Earthquakes are very frequent in the Azores: twenty years before the period mentioned, a mountain in St. Michael was overturned by a dreadful earthquake *.

"In the month of September, 1627, an earthquake levelled one of the two mountains of Manilla, called Carvalos, in the province of Cagayon. In 1645, a third part of the city was destroyed by a similar accident, and 300 persons perished in the ruins. The following year it was visited by another; and the old Indians tell us, that earthquakes are now less destructive than formerly; but they still build their houses of wood, in which they are imitated by the Spaniards.

"The number of volcanos in this island confirms the above relation; for, at certain intervals, they vomit forth flames, shake the earth, and produce all the effects ascribed by Pliny to the eruptions of Vesuvius, such as changing the beds of rivers, making the neighbouring parts of the sea retreat, covering the places adjacent with ashes, projecting stones to great distances, and making reports louder than those of cannons †."

"In 1646, an earthquake split a mountain in the island of Machian, and the explosion made a frightful noise. From the cleft issued such a quantity of flames as consumed several plantations with their inhabitants. This prodigious aperture was to be seen in the year 1685, and it

* Gen. Hist. of Voyages, vol. i. p. 325.

† See Voyage de Gemelli Careri, p. 129.

probably remains to this day. It was called the Wheel-track of Machian, because it ran from the top to the bottom of the mountain, and, at a distance, had the appearance of a high road *."

The History of the French Academy mentions, in the following terms, the earthquakes which happened in Italy during the years 1702 and 1703. "They began in October, 1702, and continued till July, 1703. The city of Norcia, with its dependencies in the Ecclesiastical State, and the province of Abruzzo, suffered most; and the earthquakes were first felt in those places which are situated at the foot of the Appennines, on the south side.

"They were frequently accompanied with frightful noises in the air, and these noises were sometimes heard when the earth was at rest, and the sky serene. The most violent concussion was on the 2d of February, 1703; and it was attended, especially at Rome, with a remarkable clear sky, and a great calmness in the air. At Rome it lasted half a minute, and at Aquila, the capital of Abruzzo, three hours. Beside ravaging the neighbouring country, it destroyed the whole town of Aquila, and buried 5,000 persons under its ruins.

"The concussions, or vibrations, of the earth, as was discovered by the motion of the lamps in the churches, were nearly from south to north.

"The earth opened in two places, and discharged, with violence, great quantities of stones,

* See l'Hist. de la Conquête des Moluques, tom. iii. p. 318.

which covered a whole field, and rendered it barren. After the stones, these apertures threw up water above the elevation of the highest trees. This discharge continued a quarter of an hour, and laid the neighbouring country under water. The water was whitish, like soap-suds, and had no particular taste.

"On the top of a mountain near Sigillo, a village about twenty-two miles from Aquila, there was a considerable plain, surrounded with rocks like a wall. The earthquake of the 2d of February converted this plain into a large unequal gulf, its greatest diameter being twenty-five fathoms, and its least twenty. This gulf has been sounded with ropes of 300 fathoms, without reaching the bottom. At the time that the gulf was formed, flames were observed to issue out of the mountain, and afterwards a thick smoke, which continued, with some interruption, for three days.

"At Genoa, they had two slight concussions on the 1st and 2d days of July, 1703, the last of which was only felt by the people on the Mole. The sea, at the same time, sunk six feet in the port, and continued in this situation a quarter of an hour.

"The sulphureous water on the road between Rome and Tivoli sunk two feet and a half, both in the basin and in the canal. The springs and rills of water, which rendered many places of the plain called Testine marshy, were entirely dried up. The depth of the water in the lake called l'Enfer was diminished three feet. In

place of the old springs, new ones, about a mile distant, appeared: they are probably the same waters, the courses of which have been changed by the concussion of the earth *."

The same earthquake, which, in 1538, formed the Monti de Cinere, near Puzzoli, filled the Lucrine Lake with stones, earth, and ashes, and converted it into a marsh †.

"Earthquakes, also," says Mr. Shaw, "have sometimes been felt at sea. In the year 1724, when I was aboard the Gazella, an Algerine cruiser of fifty guns, bound to Bona to relieve the garrison, we felt three prodigious shocks, one after another, as if a weight, at each time, of twenty or thirty ton, had fallen from a great height upon the ballast. This happened when we were five leagues to the southward of the Seven Capes, and could not reach ground with a line of 200 fathoms. The captain told me, that, a few years before, when he was upon a cruise, he felt a much greater one, at the distance of forty leagues to the westward of the rock of Lisbon ‡."

Schouten, speaking of an earthquake which happened in the Moluccas, says, "that the mountains were shaken, and that the vessels at anchor in thirty or forty fathom water were shocked, as if they had run ashore, or struck against rocks. We learn," continues he, "from daily experience, that the same happens in the ocean, where

* See l'Hist. de l'Acad. des Sciences, ann. 1704.

† See Ray's Discourses, p. 12. ‡ Shaw's Travels, p. 151.

no bottom can be found; and that earthquakes agitate vessels, even when the sea is perfectly calm *."

Gentil, in his voyage round the world, has the following remarks upon earthquakes:

"1. That half an hour before the earth begins to shake, all animals appear to be seized with a panic. The horses neigh, break their halters, and run out of the stable; the dogs bark; the birds, as if stupid, fly for shelter into the houses; the rats and mice come out of their holes, &c.

"2. That ships at anchor are so violently agitated, that all the parts of which they are composed seem to be torn asunder; their guns break loose, and their masts spring: these facts I should hardly have credited, if they had not been confirmed to me by the unanimous testimony of many witnesses. I know that the bottom of the sea is a continuation of the land; and that agitations of the one must be communicated to the other; but I could not comprehend how the different parts of a vessel, swimming in a fluid, should be affected in the same manner as if she had been resting on the ground. Her motion, I imagined, should have only resembled that produced by a storm; besides, in the present instance, the surface of the sea was smooth, and the whole agitation must have proceeded from some internal cause, because, at the time of the earthquake, there was no wind.

* Voyages, vol. vi. p. 103.

"3. That if the cavern of the earth, which contains the subterraneous fire, runs from north to south, and if the buildings of a town above it lie in the same direction, the whole houses are overturned; but, if the vein or cavern runs across the town, the damage produced by the earthquake is less considerable*."

When a new volcano breaks out in countries subject to earthquakes, they almost entirely cease, and are seldom felt, except during great eruptions, as has been observed with regard to the island of St. Christopher†.

The enormous ravages produced by earthquakes have induced some naturalists to imagine, that mountains, and all the other irregularities on the surface of the globe, have derived their origin from succussions of the earth occasioned by the action of subterraneous fires. This, for instance, is the opinion of Mr. Ray. He believes that all the mountains have been formed by earthquakes, or by the explosions of volcanos, in the same manner as Monti de Cinere in Italy, the new island near Santorini, &c. But he has not considered that the small elevations formed by earthquakes, or by the eruptions of volcanos, are not, like all other mountains, composed of horizontal strata; for, by digging into the Monti de Cinere, we find calcined stones, ashes, burnt earth, iron dross, pumice stones, all blended together like a heap of rubbish. Besides, if earth-

* See Voyage de M. le Gentil, tom. i. p. 172.

† See Phil. Trans. abridg. vol. ii. p. 392.

quakes and subterraneous fires had raised the great mountains of the earth, as the Cordeliers, Mount Taurus, the Alps, &c., the prodigious force requisite to elevate these enormous masses would, at the same time, have destroyed a great part of the surface of the globe. Earthquakes sufficient to produce such effects must have been inconceivably violent, since the greatest of them recorded in history have not been able to produce a single mountain. In the reign of Valentinian I., for instance, an earthquake was felt over the whole known world *, and yet it raised not a single mountain.

It is capable of demonstration, however, that though an earthquake should have a force sufficient to raise the highest mountains, this force would not be able to displace the rest of the globe.

For, let it be supposed, that the chain of high mountains which traverses South America from the point of Terra Magellanica to New Granada and the gulf of Darien, had been suddenly elevated by an earthquake, and then let us estimate the effect of this explosion. This chain of mountains is about 1,700 leagues long, and, at a medium, forty leagues broad, including the Sierres, which are lower than the Andes. This gives a surface of 68,000 square leagues. The thickness of the matter displaced by the earthquake I suppose to be one league; or, that the

* Ammian. Marcellin. lib. xxvi. c. 14.

mean height of the mountains from their summits to the caverns, which, agreeable to this hypothesis, must support them, is one league. The force of the explosion, therefore, must have elevated, to the height of a league, a quantity of earth equal to 68,000 cubic leagues. But, action and reaction being equal, this explosion must have communicated an equal quantity of motion to the whole globe. Now, the whole globe consists of 12,310,523,801 cubic leagues. From this number take 68,000, and there remains 12,310,455,801 cubic leagues, of which the quantity of motion would be equal to that of 68,000 elevated one league. Hence it appears, that the force necessary to raise 68,000 cubic leagues would not be sufficient to displace the whole globe a single inch.

There is no absolute impossibility, therefore, in the supposition, that the mountains have been raised by earthquakes, were it not evident, both from their internal structure and their external figure, that they have been formed by the operation of the waters of the ocean. Their interior parts are composed of parallel strata, interspersed with sea shells; and their external figure consists of angles every where corresponding. Is it credible that this uniform structure, and regular figure, could have been produced by sudden and desultory succussions of the earth?

But, as this notion has been embraced by some philosophers, and as the nature and effects of earthquakes are not well understood, I shall

hazard a few ideas, which may, perhaps, throw some light upon this intricate subject.

The surface of the earth has undergone many changes. At considerable depths, we find holes, caverns, subterraneous rivulets, and voids, which sometimes communicate with each other by means of chinks and fissures. There are two species of caverns: the first are those which have been formed by volcanos and the action of subterraneous fires. The action of subterraneous fire elevates, shakes, and throws off to a distance the superincumbent materials; at the same time, it splits and deranges those on each side of it, and thus produces caverns, grottos, and irregular hollows. But such effects are only exhibited in the neighbourhood of volcanos, and are not so frequent as the other species of caverns, which are produced by the operation of water. It has already been remarked, that the different strata of the earth are all interrupted by perpendicular fissures, the origin of which shall be afterwards explained. The waters which fall upon the surface descend through those fissures, collect when their progress is prevented by a stratum of clay, and form springs and rivulets. From the nature of water, it searches for cavities or small vacuities, and has a constant tendency to force a passage, till it finds a proper vent. Wherever it goes, it carries along with it sand, gravel, and other bodies which it is capable of dividing or dissolving. In this manner, the operation of water proceeds till it forms subterraneous passages; and then it breaks out in the

form of fountains, either on the surface of the earth, or in the bottom of the sea. The materials it perpetually carries off leave hollows or caverns in the bowels of the earth, which are often of great extent; and these caverns have a very different origin from those produced by volcanos or earthquakes.

Earthquakes are of two kinds: those occasioned by the action of subterraneous fires, and by the explosions of volcanos, are only felt at small distances, previous to, or during the time of eruptions. When the inflammable matters in the bowels of the earth begin to ferment and to burn, the fire makes an effort to escape in every direction; and if it finds no natural vents, it forces a passage, by elevating and throwing off the incumbent earth. In this manner volcanos commence, and their effects continue in proportion to the quantity of inflammable matter they contain. When the quantity of inflamed matter is inconsiderable, it produces only an earthquake, and exhibits no marks of a volcano: the air generated by subterraneous fire may also escape through small fissures; and, in this case, likewise, it will be attended with a succussion of the earth; but no volcano will appear. But when the quantity of inflamed matter is great, and when it is confined on all sides by solid and compact bodies, an earthquake and a volcano are the necessary consequences. All these commotions, however, constitute only the first species of earthquakes, which are not felt but in the neighbourhood of the places where they happen.

A violent eruption of Ætna, for example, will shake all the island of Sicily; but it will never extend to the distance of 300 or 400 leagues. When Vesuvius bursts open a new mouth, it excites an earthquake in Naples and in the neighbourhood of the volcano; but these earthquakes never shake the Alps, nor do they extend to France, or other countries distant from Vesuvius. Thus earthquakes, produced by volcanos, are limited to a small place; they are nothing but effects of the reaction of the fire, and they shake the earth in the same manner as the explosion of a powder-magazine occasions an agitation to the distance of several leagues.

But there is another species of earthquakes, which are very different in their effects, and perhaps also in their cause. These earthquakes are felt at great distances, and shake a long tract of ground without the intervention either of a new volcano, or of eruptions in those which already exist. There are instances of earthquakes which have been felt at the same time in Britain, in France, in Germany, and in Hungary. These earthquakes always extend more in length than in breadth. They shake a zone or belt of earth with greater or less violence in different places; and they are generally accompanied with a hollow noise, like that of a heavy carriage rolling with rapidity.

As to the causes of this species of earthquake, it must be remarked, that the explosion of all inflammable substances, like that of gunpowder, generates a great quantity of air; that this air,

is highly rarefied by heat; and that its effects, from the compression it receives by being confined in the bowels of the earth, must be exceedingly violent. Let us suppose, that, at the depth of 100 or 200 fathoms, there is a vast collection of pyrites and sulphureous bodies, and that they are inflamed by the fermentation produced by the admission of water to them, or by other causes. What must be the effect? In the first place, these substances are not placed in horizontal beds, like the ancient strata, which were formed by the sediments of the waters. They are lodged, on the contrary, in the perpendicular fissures, in subterraneous caverns, and other places, to which the water has access. When inflamed, they generate a vast quantity of air, the spring of which, by being compressed within a small space, like that of a cavern, will not shake the earth immediately above, but it will search for passages, in order to expand and make its escape. Caverns and channels of subterraneous rivulets and springs, are the only natural passages for this rarefied air. Into these, therefore, it will rush with impetuosity, and produce in them a furious wind, the noise of which will be heard on the surface; and it will be attended with vibrations or succussions of the ground. This subterraneous wind produced by fire will extend the whole length of the caverns or channels, and occasion a shaking, more or less violent, in proportion to its distance from the heat, and to the width or narrowness of the canals. But this motion must necessarily

run in a longitudinal direction; and the shaking, of course, must be felt over a long belt of ground. This air, however, cannot produce an eruption or a volcano; because it finds sufficient room for expanding itself, and diminishing its force, or, rather, because it escapes through fissures in the form of vapour or of wind. But, although the existence of caverns or channels for the passage of this rarefied air should be denied, it is easy to conceive that, in the very place where the explosion is made, as the earth is elevated to a considerable height, the neighbouring places must split horizontally in attempting to yield to the impulse communicated by the original motion; and, in this manner, passages may be gradually and successively opened, so as to communicate with very distant places. This explication corresponds with all the phænomena. Earthquakes are not felt at great distances at the same minute, or even the same hour. They are not accompanied with eruptions, or external fire; and the noise almost constantly marks the progressive motion of the subterraneous wind. Other facts concur in establishing this theory. Blasts of wind, and vapours, sometimes of a suffocating nature, it is well known, arise from mines, independent of the motion of the air produced by the current of water. It is equally well known, that winds issue from certain apertures of the earth, from caverns, abysses, and deep lakes, as Lake Boleslaw in Bohemia, which has been formerly mentioned.

Earthquakes are produced by two causes:

the first is the sudden sinking of cavities in the bowels of the earth; and the second, which is still more frequent and more violent than the first, is the action of subterraneous fires.

When a cavern sinks in the middle of a continent, it produces a commotion which extends to a greater or smaller distance, in proportion to the quantity of motion excited by the fall of this mass of earth; and, if this mass is inconsiderable, or falls from no great height, it will not produce a succussion so violent as to be perceived at a great distance; the effect is limited to the neighbourhood of the sunk cavern; and if the movement is propagated to greater distances, it is only by slight tremblings or vibrations.

As most of the primitive mountains rest upon caverns, because, at the moment of their consolidation, these eminences were blown up by the action of the internal fire, sinkings in the mountains have happened, and still happen, whenever the vaults of the caverns are undermined by water, or shaken by any convulsion. An entire portion of a mountain sometimes sinks perpendicularly, but oftener inclines, and not unfrequently reverses. Of this we have striking examples in several of the Pyrennees, where the strata, formerly horizontal, are often inclined more than forty-five degrees; which shows, that the entire mass of each portion of the mountain, whose strata were parallel to each other, has inclined by the lump, and, in the moment of its sinking, rested upon a base inclined to the horizon forty-five degrees. This

is the most general cause of the inclination of strata in mountains. For the same reason we often find, between the adjacent eminences, strata which descend from the first and rise to the second, after having traversed the valley. These strata are horizontal, and are bedded at the same height in the two opposite hills, between which the cavern had fallen in. The earth sinks down, and the valley is formed, without producing any other derangement than a greater or smaller inclination of the strata, according to the depth of the valley, or the declivity of the two opposite hills.

This is the only sensible effect of the sinking of caverns in mountains and other parts of continents. But whenever this effect happens in the bottom of the sea, where sinkings must be more frequent than on the land, because the water perpetually undermines the vaults in every place where they support the bottom of the ocean, these sinkings not only derange and incline the strata, but sensibly lower the level of the sea. From the first occupation of the waters, their level has been depressed 2,000 fathoms by these sinkings; and, as all the submarine caverns have not yet fallen in, it is more than probable, that the basin of the sea, by growing more and more deep, will lessen its surface, and, of course, that the extent of all the continent will always continue to augment by the retreat and sinking of the waters.

A second and more powerful cause than the first concurs in producing the same effect. This

cause is the rupture and sinking of caverns by the action of submarine fires. It is certain, that no motion or sinking in the bottom of the sea can happen without diminishing its surface: and, if we consider the general effects of subterraneous fires, we will perceive that, as long as there is fire, the commotions of the earth will not be confined to simple tremblings; for the efforts of fire raise and open the sea and the land by violent and reiterated succussions, which not only overturn and destroy the adjacent lands, but shake those that are distant, and ravage or derange every thing in the route of their direction.

The earthquakes occasioned by subterraneous fires generally precede eruptions of volcanos, and sometimes cease the moment the fire opens a passage through the earth, and carries its flames into the air. These dreadful earthquakes sometimes continue during the whole time of eruptions. These two effects are intimately connected. There is never a great eruption of a volcano without being preceded, or at least accompanied, with an earthquake. But we often feel very violent succussions of the earth without any eruption of fire. Those movements, in which fire has no part, proceed not only from the first cause, the falling in of caverns, but likewise from the action of subterraneous winds and storms. There are many examples of lands raised or sunk by the force of these internal winds. Sir William Hamilton, a man as respectable for his private character as admirable for the extent

of his knowledge and researches on this subject, told me, that he had seen, between Trente and Verona, near the village of Roveredo, several little hills composed of large masses of calcarious stones, which had evidently been raised by different explosions of subterraneous winds. There is no indication of the action of fire upon any of these rocks or their fragments. The whole country, on both sides of the highway, for an extent of near a league, has, from place to place, been overturned by the prodigious efforts of subterraneous winds: the inhabitants say that it happened suddenly, and was the effect of an earthquake.

But the force of the wind, however violent, appears not to be a cause sufficient to produce such great effects; and, though there be no marks of fire in these little hills, raised by the commotion of the earth, I am persuaded that they have been elevated by electrical explosions of subterraneous thunder, and that the internal winds have contributed to this effect solely by producing electrical storms in the cavities of the earth. Hence all convulsive movements of the earth may be referred to three causes: the first and most simple is the sinking of caverns; the second, storms and subterraneous thunder; and the third, the action of fire kindled in the interior parts of the globe. It is easy to ascribe to one or other of these three causes all the phænomena which accompany or succeed earthquakes.

Commotions of the earth sometimes give rise

to eminences; but they more frequently produce gulfs. On the 15th day of October, 1773, a gulf opened in the territory of Induno, in the state of Modena, the cavity of which was more than 400 fathoms wide by 200 deep*. In 1726, a mountain of a considerable height, situated in the northern part of Iceland, was sunk in one night by an earthquake, and a very deep lake assumed its place. The same night, about a league and a half distant, an ancient lake, the depth of which was unknown, was entirely dried up, and its bottom raised in such a manner as to form a pretty high hill, which still exists †. In the seas in the neighbourhood of New Britain, M. Bougainville remarks, earthquakes have terrible effects on navigation. On the 17th of June, the 12th and 27th of July, 1768, there were three earthquakes at Boero, and, on the 22d of the same month, one at New Brittany. These earthquakes sometimes annihilate islands and known sand-banks, and sometimes create them ‡.

There are earthquakes which extend to great distances; but they are always longer than broad. One of the most considerable was that felt in Canada, in the year 1663. It extended more than 200 leagues in length and 100 in breadth, *i. e.* more than 20,000 superficial leagues. The effects of the last earthquake in Portugal, which happened in our own time, were felt still farther.

* Journ. Hist. et Politique, Dec. 10, 1773, art. Milan.

† Melanges interassans, tom. i. p. 159.

‡ Voyage autour du Monde, tom. ii. p. 278.

M. le Chevalier de Saint-Sauveur, king's commandant at Merucis, informed M. de Gensanne, that, when walking on the left margin of Jouante, in Languedoc, the sky suddenly became very dark, and that, in a moment after, he perceived, at the foot of the hill, which is situated to the right of that river, a terrible bright globe of fire: immediately there arose from the bowels of the earth a considerable mass of rocks, and the whole chain of mountains split from Merucis to Florac, an extent of near six leagues. This rent, in some places, is more than two feet wide, and has partly fallen in*. There are other earthquakes which produce little or no commotion. Kolbe relates, that, on the 24th of September, 1707, from eight to ten o'clock before noon, the sea rose upon the land at the Cape of Good Hope, and descended seven times successively, and with such rapidity, that, from one moment to another, the place was alternately covered and left by the waters †.

With regard to the effects of earthquakes, the falling of mountains, and the sinking of caverns, I shall subjoin a few facts, which are both recent and well attested. In Norway, a whole promontory, called Hammersfields, suddenly fell ‡. A very high mountain near that

* Hist. Nat. de Languedoc, par M. de Gensanne, tom. i. p. 231.

† Descript. du Cap de Bonne-Esperance, tom. ii. p. 237.

‡ Hist. Nat. de Norwége, Pontoppidan; Journal Etranger, Août, 1755.

of Chimboraço, one of the highest of the Cordeliers, in the province of Quito, tumbled down in a moment. This fact, with all its circumstances, is related in the Memoirs of M. de la Condamine and Bouguer. Similar fallings and sinkings often happen in the southern islands of India. At Gamma-canore, where the Dutch have a settlement, a high mountain fell suddenly in the year 1673, when the weather was fine: it was followed by an earthquake, which overturned the neighbouring villages, and destroyed several thousands of persons *. On the 11th of August, 1772, in the island of Java and province of Cheribou, one of the richest settlements of the Dutch, a mountain, of about three leagues in circumference, suddenly sunk, and rose and sunk alternately like waves in a stormy ocean: it at the same time threw out many globes of fire, which were seen at a great distance, and gave a light as brilliant as that of day: all the plantations, together with about 2,140 inhabitants, without reckoning strangers, were entirely swallowed up †. We might recite many other examples of the sinking of lands and swallowing of mountains by the rupture of caverns, and the succussions occasioned by earthquakes and the action of volcanos: but we have said enough to establish the general conclusions we have drawn from the facts already related.

* Hist. Gen. des Voyages, tom. xvii. p. 54.

† See Gazette de France, 21 Maii, 1773, art. de la Haie.

When these remarks are considered, I cannot comprehend how the mountains should have originated from earthquakes, since the mineral and sulphureous bodies which occasion them are seldom to be met with but in the perpendicular fissures of mountains, and in other cavities of the earth, the greatest number of which have been produced by the operation of water; since these inflammable substances produce only a momentary explosion, and violent winds, which follow the channels of subterraneous waters; since the duration of earthquakes on the surface of the earth is so short, they must be occasioned by a sudden explosion, and not by a continued conflagration; and, *lastly*, since those earthquakes, which extend over large tracts of ground, never produce the smallest eminence throughout their whole course.

Earthquakes, it is true, are more frequent in the neighbourhood of volcanos, as in Sicily, and the environs of Vesuvius: but it appears, from repeated observations, that these earthquakes are very limited, and, consequently, can never form a chain of mountains.

It has sometimes been remarked, that the matters ejected from Ætna, after cooling for several years, and being afterwards moistened with rain, have rekindled, and thrown out flames with such violent explosions, as to occasion small earthquakes.

In 1669, during a violent eruption of Ætna, which began on the 11th of March, the summit

of the mountain sunk considerably*; which is a proof that this volcano proceeds rather from the superior part of the mountain than from the bottom of it. Borelli, who is of the same opinion, observes, "that the fire of a volcano proceeds neither from the centre, nor from the bottom of a mountain, but from the top; and that the inflammation never kindles but at a small depth †."

Mount Vesuvius has frequently thrown out, during eruptions, great quantities of boiling water. Mr. Ray, who imagines that the fire of volcanos comes from a very great depth, says, that this water proceeds from the sea, which communicates, by subterraneous passages, with the foot of the mountain. As a proof, he mentions the remarkable dryness of the top of Vesuvius, and the agitation of the sea during eruptions, which sometimes recedes so far as to leave the port of Naples entirely dry. But, supposing these facts to be true, they by no means prove that the fire of volcanos proceeds from a great depth; for the water they eject is certainly rain-water, which penetrates through the fissures, and collects in the cavities of the mountain. Rills and springs issue from the tops of volcanos, as well as from other high mountains; and, as the former are hollow, and have suffered more concussions than the latter, nothing can be more

* See Phil. Trans. abridg. vol. ii. p. 387.

† Borelli de incendiis Montis Ætnæ.

natural than that they should collect water in their caverns, and that this water should sometimes be ejected, along with other substances, in the time of eruptions. With regard to the motion of the sea, it arises solely from the shock communicated to the waters by the explosion, which makes them advance or retire according to different circumstances.

The most common substances thrown out by volcanos are torrents of melted minerals, which overflow the environs of the mountain. These rivers of lava extend to great distances; and, in cooling, they form beds, either horizontal or inclined, in the same manner as the strata accumulated by successive sediments from water. But the former are easily distinguishable from the latter: 1. Because strata of lava are not every where equal in thickness. 2. Because they contain nothing that has not evidently been calcined, vitrified, or melted. 3. Because their extent is more limited. As there is a vast number of volcanos in Peru, and as the bottoms of most of the Cordeliers are covered with substances which have been thrown out by eruptions, it is not surprising that no sea shells have been found there; for they must have been calcined and destroyed by the fire. But I am still persuaded, that, if the clay ground, which, according to M. Bourguet, is the ordinary earth in the valley of Quito, had been dug, shells would have been discovered there, as well as every where else, especially where the ground is not covered, like the bot-

toms of the mountains, with matters ejected from volcanos.

It has often been asked, Why all volcanos appear in high mountains only? I have partly solved this question in the preceding article. But, before finishing the present subject, I shall endeavour more fully to explain myself.

The peaks or points of mountains were originally covered with earth and sand, which, after being gradually washed down to the valleys by the rains, left nothing but those bare rocks or stones called the core of mountains, which, being likewise subjected to the action of the weather, small and large fragments of them must have been occasionally loosened, and, of course, must have rolled down to the plains. The rocks at the base of the summit being fully uncovered, and having lost their original support from the sand and earth, would necessarily give way a little, and, by separating from each other, would produce small intervals. But this yielding of the lower rocks could not take place without rending those which lay above them. In this manner the core of the mountain, from the summit to the base of the lower rocks, would be split into an infinite number of perpendicular fissures of different dimensions. Through these the rains would penetrate, and carry along with them, into the bowels of the mountain, all the minerals, and other substances which they were capable of transporting or dissolving. Here pyrites, sulphur, and other combustible substances, would be

produced; and, in the course of time, these bodies would accumulate in great quantities, and, by their fermentation, would give rise to explosions, and other effects of volcanos. Heaps of these mineral substances might likewise exist in the heart of the mountain, before the rain could penetrate so deep. In this case, as soon as the air or rain got access to them by means of the perpendicular fissures, a conflagration and volcano would instantly take place. No such phænomena can be exhibited in plains; for, as every thing there is at rest, and nothing can be displaced, it is not surprising that the existence of volcanos should be confined entirely to the mountains.

When coal mines are opened, which are commonly found in clay grounds, and at a great depth, the mineral substances above mentioned sometimes kindle into flames. There are examples in Scotland, Flanders, &c., of coal mines which have continued to burn for many years. The admission of air is alone sufficient to produce this effect. But these inflammations occasion only slight explosions, and never form volcanos; because, in such places, all being plain and solid, the fire cannot be excited to such a degree as in burning mountains, which are full of caverns and cliffs, through which the air penetrates, and augments the action of the fire so forcibly, as to give rise to the terrible effects we have been describing.

Of extinguished Volcanos.

The number of extinguished volcanos exceeds incomparably that of those which are active. They are very numerous in almost every part of the earth. I might mention those remarked by M. de la Condamine in the Cordeliers, and by M. Frenayé in St. Domingo *, near Port-au-Prince, and those of Japan and the other eastern and southern islands of Asia, the whole of which countries have been formerly ravaged by fire. But I shall limit myself to the extinguished volcanos of the isles of France and Bourbon, which have been recognised by some enlightened voyagers.

"The soil of the isle of France," says M. l'Abbé de la Caille, "is covered with a prodigious number of stones of all sizes, which are of a blackish ash colour. Many of them are full of holes, like a sieve. Most of them contain a great quantity of iron; and the surface of the earth is covered with the ore of this metal. We likewise find, especially on the north coast of the island, a great many pumice stones, lavas, or refuse of iron, profound grottos, and other manifest vestiges of extinguished volcanos. . . .

"The isle of Bourbon," continues M. l'Abbé de la Caille, "though larger than the isle of France, is only a large mountain, split as it were from its summit into three different parts. Its

* Note communicated to M. de Buffon, by M. Frenaye, March 10, 1777.

top is covered with wood, and inhabited; and two thirds of its declivity, which extends as far as the sea, are cleared and cultivated. The rest is covered with the lavas of a volcano, which burns slowly and without any noise. It seems not to burn much, except during the rainy seasons. . . .

"Ascension Island has visibly been formed and burnt by a volcano. It is covered with a red earth, similar to brick-dust or burnt clay. . . . . The island is composed of several mountains from 100 to 150 fathoms high. There is one still larger to the south of the island, which is about 400 fathoms in height. . . . . Its summit is double and lengthened: but all the others are pretty perfect cones, and covered with red earth. The land and part of the mountains are interspersed with prodigious quantities of rocks full of holes, like sieves, and with very light calcarious stones, a number of which resembled coagulated milk; some of them were laid over with a dirty white varnish, approaching to green. Pumice stones are likewise very frequent*."

The celebrated captain Cook remarks, that, in an excursion to the interior parts of Otaheite, they found burnt rocks, like those of Madeira; that all the stones bore incontestible marks of fire; that they likewise perceived traces of fire in the clay upon the hills; and that Otaheite and a number of adjacent islands might be supposed to be the relics of a continent which had been swal-

* Mem. de l'Acad. des Sciences, ann. 1754, pp. 111, 121, and 126.

lowed by the explosions of subterraneous fire*. Philip Carteret tells us, that one of the Charlotte islands, situated in the 11° 10′ of south latitude, is of a prodigious height and a conical figure; that its summit is like a funnel, from which smoke issues, but no flames; and that, on the most southern coast of New Britain, there are three mountains, from one of which proceeds a large column of smoke*.

We find basalts in the isle of Bourbon, where the volcano, though feeble, still acts: in the isle of France, where all the fires are extinct; and in Madagascar, where there are both active and extinguished volcanos. But, to mention no other basalts but those of Europe, we know that there are considerable masses of them in Ireland, in Britain, in Auvergne, upon the borders of the Elbe, in Misnia upon Mount Cattener, at Marienburg, at Weilbourg in the county of Nassau, at Lauterback, at Billstein, in several parts of Hesse, in Lusace, in Bohemia, &c. These basalts are most beautiful lavas, produced, in all these countries, by volcanos which are now extinct. But we shall content ourselves with abridged descriptions of extinguished volcanos in France.

"The mountains of Auvergne," says M. Guettard, "which have formerly, in my estimation, been volcanos . . . . are those of Volvic, two leagues from Riom; of Puy-de-dôme, near Chermont; and of Mount Or. The volcano of Vol-

* Cook's Voyage, tom. ii. p. 431.

† Carteret's Voyage, pp. 250 and 275.

vic has formed, by its different lavas, strata lying upon each other, and composing enormous masses, in which quarries are dug, and furnish stones to several places at a distance. . . . . . It was at Moulins where I first discovered lava; . . . . and being at Volvic, I perceived that the mountain was almost entirely composed of matters which had been thrown out by the eruptions of volcanos.

"The figure of this mountain is conical, and its base consists of rocks of a grayish white granite, or of the colour of a pale rose. . . . . The rest of the mountain is composed entirely of blackish or reddish pumice stones, heaped upon each other without order or connexion. . . . About two thirds up the mountain, we meet with irregular rocks, bristled with misshapen points turned to all sides, and of an obscure red or dirty black. They are solid and hard, and have no holes like the pumice stones. . . . . Before arriving at the summit, we find a hole of some fathoms wide, and of a conical figure, approaching to that of a funnel. . . . . The part of the mountain to the north and east, appeared to be solely composed of pumice stones. . . . . In Volvic, the beds of stone follow the inclination of the mountain, and seem to be continued through it, and to communicate with those discovered by the ravines a little below the summit . . . . These stones are of an iron-gray colour, and seem to have a white grain, which comes out on the surface like an efflorescence: though spongy, and full of small irregular holes, they are hard.

"Mount Puy-de-dôme is nothing but a mass

of matter which indicates the dreadful effects of the most violent fire. . . . . In those places of the mountain which are not covered with plants and trees, we travel among pumice stones, pieces of lava, and a gravel or sand, formed by a kind of iron dross and small bits of pumice stones mixed with ashes.

"These mountains exhibit several peaks, and all of them have cavities or funnels of greater or smaller dimensions. One of these peaks, the road which leads to it, and the whole space as far as Puy-de-dôme, are only vast heaps of pumice stones. The same observation is applicable to the other peaks, which are fifteen or sixteen in number, situated in the same line from south to north, and all of them furnished with funnels.

"The top of the peak of Mount Or is a rock composed of a tender whitish ash-coloured stone, similar to that on the summits of all the mountains in this volcanic country: it is only a little lighter than that of Puy-de-dôme.

"If I found not on this mountain as many vestiges of a volcano as in the other two, it must be partly ascribed to this circumstance, that Mount Or is more covered, through its whole extent, with trees and shrubs, than Mounts Volvic and Puy-de-dôme. . . . . However, the south-east part is entirely bare, and entirely composed of stones and rocks, which seem to have been exempted from the effects of the fire. . . . .

"But the peak of Mount Or is a cone similar to those of Volvic and Puy-de-dôme. To the

east of this point is the Peak du Capuchin, which is likewise conical, but not so regular as those of the preceding mountains. It even appears that this peak has undergone more changes in its structure; for every thing is more irregular, and broken into smaller portions. . . . There are still several other peaks, the bases of which rest upon the ridge of the mountain; but they are all overtopped by Mount Or, which is 509 fathoms high. . . . The peak of Mount Or is very rugged: it terminates in a point about fifteen or twenty feet in diameter. . . . . .

"There are several conical mountains between Thiers and Saint Chaumont, which led me to think," says M. Guettard, "that they might have been burnt. . . . Though I have never been at Pontgibault, I have sufficient proofs to convince me that the mountains of this canton are extinguished volcanos; I have received fragments of lava from them, which it was easy to recognise by the yellow and blackish points of vitrified matter, which are the most certain characteristics of volcanic productions *."

The same M. Guettard and M. Faujas have found, on the left bank of the Rhone, and a good way into the country, very large fragments of basaltic columns. . . . In ascending into the Vivarais, they found in a rapid brook a vast collection of volcanic matter, which they followed to its source. It was not difficult to recognise the volcano. It is a very high moun-

* Mem. de l'Acad. des Sciences, ann. 1752, p. 27—58.

tain, on the top of which they found a mouth of about eighty feet in diameter. Below this mouth the lava is partly visible. It has flowed down the ravines, in great masses, for the space of seven or eight thousand fathoms. The matter has heaped together while yet burning in certain places: and, after fixing, it chapped and split through its whole thickness, and left the plain entirely covered with innumerable columns, from fifteen to thirty feet long by about seven inches in diameter*.

" Having proceeded to Montferrier," says M. Montet, " a village about a league distant from Montpelier. . . . . . I found a number of black stones, detached from each other, and of different figures and sizes. . . . I compared them with others, which were unquestionably the production of volcanos. . . . . and found them to be of the same nature. Hence I no longer doubted that these stones of Montferrier were a very hard lava, or a matter melted by a volcano, which had long been extinguished. The whole mountain of Montferrier is interspersed with these stones, and the streets are paved and the village partly built with them. . . . . The surfaces of these stones are, in general, full of holes or porosities, which sufficiently indicate that they have been formed of matter melted by a volcano. This lava is dispersed over all the grounds adjacent to Montferrier. . . . .

* Journal de Physiques, par M. l'Abbé Rozier; mois de Decembre, 1775, p. 516.

"On the side of Pézenas, extinguished volcanos are very numerous. . . . . The whole country is full of them, especially from Cap d'Agde, which itself is an extinguished volcano, to the foot of that chain of mountains that commences five leagues to the north of this coast, and upon their declivity, or at a little distance from them, are situated the villages of Livran, Peret, Fontés, Néfiez, Gabian, and Faugéres. In going from south to north, we find a remarkable plinth or chaplet, which begins at Cap d'Agde, and comprehends Mount Saint Thibery and Causse (mountains situated in the middle of the plains of Bressan), the peak of Valros in the territory of this village, the peak of Montredon in the territory of Tourbes, and that of Saint Marthe, near the royal priory of Cassan. Besides, from the foot of the mountain, a great and long mass arises, and terminates to the south near the Granges of Prés, and from east to west between the village of Caus and that of Nizas. . . . . It is to be remarked of this canton, that it consists of almost nothing but a mass of lava, and that in the middle of it there is a round mouth, or distinct crater, about 200 fathoms in diameter, which formed a pond that has since been drained by a deep cut through the hard lava, which is disposed into strata, or rather contiguous undulations. . . . .

"In all these places we find lava and pumice stones. Almost the whole village of Pézenas

is paved with lava. The rock of Agde is nothing but a hard lava, and the whole of this village is built and paved with this lava, which is very black. . . . . Almost the whole territory of Gabian, in which is the famous fountain of Petroleum, is bestrewed with lava and pumice stones.

"We likewise find at Causse, Basan, and Saint Thibery, a considerable quantity of basalts, which are commonly prisms with six sides, and from ten to fourteen feet in length. These basalts are found in a place where the vestiges of an ancient volcano are nó longer recognisable.

"The baths of Balaruc every where present us with relics of an extinguished volcano. The stones found there are nothing but pumices of different sizes. . . . .

"In all the volcanos I examined, I remarked that the matter or stones thrown out are of various figures. Some of them are in large, heavy, and hard masses, like the rock of Agde: others, like those of Montferrier and the lava of Tourbes, are in detached pieces, of considerable weight and hardness *."

M. Villet, of the academy of Marseilles, has transmitted to the king's cabinet some specimens of lava and other matters found in the extinguished volcanos of Provence; and he writes me, that, a league from Toulon, there are evi-

* Mem. de l'Acad. des Sciences, ann. 1760, p. 466—473.

dent vestiges of an ancient volcano; and that, having descended a ravine to the foot of this old volcano of Mount d'Ollioules, he was struck with the appearance of a detached rock which had come down from the mountain. It was calcined; and, having broke off some pieces, he found in the heart some sulphureous particles, so strongly marked, that he no longer doubted the ancient existence of these volcanos, which are now extinct *.

M. Valmont de Bomare has observed, in the territory of Cologne, the vestiges of several extinguished volcanos.

I could give many other examples, which all concur in proving, that the number of extinguished volcanos is perhaps a hundred times greater than of those now actually existing. I must here remark, that, between these two, there are, as in all the other operations of Nature, intermediate states, degrees, and shades, of which we can only lay hold of the principal traits. For example, the Solfataras are neither active nor extinguished volcanos, but seem to participate of both. These no man has better described than one of our learned academicians, M. Fougeroux de Bondaroy; I shall, therefore, lay before the reader his chief observations:

"Solfatara, situated four miles west from Naples, and two miles from the sea, is surrounded

* Lettre de M. Villet a M. de Buffon; Marseille, le 8 Mai, 1775.

on all sides with mountains. Before arriving at it, we must ascend about half an hour. The space comprised between the mountains forms a basin of about 1,200 feet in length by 800 feet broad. With regard to the mountains, it lies in a bottom ; but it is not so low as the ground you traverse in going to it. The soil in the bottom of the basin is a very fine, close, beaten sand, and it is so dry and parched, that it produces no vegetables. The colour of the sand is yellowish. . . . . . The sulphur, which is found in great quantities among the sand, gives it this colour. The mountains, which bound the greatest part of the basin, consist of bare rocks, without earth or plants. Some of them are split, and their parts are burnt and calcined ; but the whole present no arrangement or order in their position. . . . . . They are covered with greater or smaller quantities of sulphur, which is sublimed in this part of the mountain and in the neighbouring basin.

" The opposite side consists of a better soil. . . . . . Neither does it present furnaces similar to those formerly mentioned, and which are common on the other side.

" In several places, we find, in the bottom of the basin, apertures or mouths, from which issue smoke, accompanied with a heat that would burn the hands smartly ; but it is not strong enough to kindle paper. . . . . .

" The adjacent places produce a heat which is felt through the shoes, and a disagreeable odour of sulphur exhales from them. . . . . . When a

sharp pointed stick is thrust into the ground, there soon issues a vapour or smoke, similar to that which exhales from the natural crevices.

"Through these apertures a small quantity of sulphur is sublimed, together with a salt which has all the characters of sal ammoniac.

"On several stones which surround Solfatara. we find threads of alum. . . . . Lastly, sulphur is collected from Solfatara. . . . This substance is extracted from grayish stones, interspersed with shining particles, which are sulphur crystallized between the stony particles. . . . These stones are sometimes impregnated with alum.

"By striking the middle of the basin with our foot, we easily perceive that the ground is hollow below.

"If we traverse the side of the mountain, where the mines are most numerous, we find lavas, pumice stones, the dross of volcanos, &c. In a word, the whole appearances, when compared with the matters at present furnished by Vesuvius, demonstrate that Solfatara was formerly the mouth of a volcano. . . . .

"The basin of Solfatara has often changed its form; and we may conjecture that it will still assume others. This territory daily hollows and undermines itself. It at present forms a vault which covers an abyss. . . . If this vault sinks, the abyss will probably fill with water, and produce a lake *."

M. Fougeroux de Bonderoy has likewise made

* Mem. de l'Acad. des Sciences, ann. 1765, p. 267—283.

some observations on Solfataras in other parts of Italy.

" I have been," says he, " at the source of a rivulet, which we pass in the road between Rome and Tivoli, the water of which has a strong odour of liver of sulphur. . . . . It forms two small lakes, about forty fathoms in their greatest extent. . . . .

" One of these lakes, according to the plumb-line we were obliged to use, was, in different places, sixty, seventy, and eighty fathoms deep. In these lakes we saw several floating islands, which sometimes change their situation. . . . . They are composed of plants reduced into a kind of light turf, upon which the waters, though corrosive, have no effect. . . . .

" The heat of these waters was twenty degrees, when the thermometer in the open air stood at eighteen degrees. Thus it appears, from experiment, that the heat of these waters is inconsiderable. . . . . They exhale a disagreeable odour; and this vapour changes the colour of vegetables and of copper *."

" The Solfatara of Viterbe," M. l'Abbé Mazeas remarks, " has a mouth of from three to four feet only. Its waters boil, exhale an odour of the liver of sulphur, and petrify their canals, like those of Tivoli. . . . . The degree of their heat is that of boiling water, and sometimes more. . . . The volumes of smoke, which sometimes arise, indicate a still greater heat; and yet the bottom

* Mem. de l'Acad. des Sciences, ann. 1770, p. 1—7.

of the basin is covered with plants, which grow in the bottom of the lakes, and in the marshes. In ferruginous soils, these waters produce vitriol, &c.* "

"In several of the Appennine mountains, and particularly in those on the road from Bologna to Florence, we find fires, or vapours which require only the approach of a candle to inflame them. . . . .

"The fires of Mount Cenida, near Pietramala, are situated at different heights of the mountain, upon which we find four mouths that throw out flames. . . . . One of these fires is in a circular place surrounded with a rising ground. . . . . Here the earth appears to be burnt, and the stones are blacker than those in the neighbourhood; there likewise issues, here and there, a lively, blue, clear flame, which rises from three to four feet high. . . . . But, beyond this circular space, we see no fire, though the heat of the ground is perceptible at the distance of sixty feet from the centre of these flames. . . . .

"Along a fissure or crevice in the neighbourhood of the fire, we hear a dull noise, like that of wind moving through a subterraneous passage. Near this place, we find two sources of hot water. . . . . The ground, in which fire has long existed, is neither depressed nor elevated. . . . . Near this fire we see no volcanic stones, nor any mark which indicates that fire has ever been

* Mem. des Savans Etrangers, tom. v. p. 325.

thrown out. However, some little hills in the neighbourhood have every appearance of having been formed, or at least changed by volcanos. . . . . In 1767, succussions of an earthquake were felt in the environs; but no change was produced on the fire, neither was the smoke increased or diminished.

"About ten leagues from Modena, at a place called Barrigazzo, there are five or six openings, where, at particular times, flames appear, which are extinguished by a strong wind: there are likewise vapours which inflame by contact with fire. . . . . But, notwithstanding the unequivocal vestiges of extinguished volcanos, which subsist in most of these mountains, the fires seen there are not new volcanos forming, because they never throw out any volcanic matter *."

Hot waters, as well as the fountains of Petroleum, and other bituminous and oily substances, should be regarded as another shade between extinguished and active volcanos. When subterraneous fires exist near strata of coal, they dissolve the coal, and give rise to most sources of bitumen: they likewise occasion the heat of the hot springs which run in their neighbourhood. But these subterraneous fires now burn with tranquillity; and we only recognise their ancient explosions by the substances they have formerly rejected. They ceased to act when the sea re-

* Mem. sur le Pétrole, par M. Fougeroux de Banderoy, dans ceux de l'Acad. des Sciences, ann. 1770, p. 45.

tired from them; and, as already remarked, I believe there is no longer any reason to dread the return of these direful explosions, since every observation concurs in showing that the sea will always retire farther and farther.

Of Lavas and Basalts.

To what we have said on the subject of volcanos, we shall add some remarks on the motion of lavas, and on the time necessary for their cooling and their conversion into vegetable soil.

The lava which runs from the foot of the eminences formed by the matters rejected by the volcano, is an impure glass in fusion. It is a tenacious, viscous, and half fluid substance. Hence the torrents of the vitrified matter, when compared to torrents of water, run slowly; and yet they often proceed to great distances. In these torrents of fire, however, there is another movement than what takes place in those of water: this movement tends to elevate the whole running mass, and is produced by the expansive force of the heat in the interior parts of the burning torrent. The external surface cools first; the liquid fire continues to run below; and, as heat acts equally on all sides, the fire, which endeavours to escape, elevates the superior parts that are already consolidated, and often forces them to rise perpendicularly. This is the origin of those large masses of lava in the form

of rocks, which are found in the course of almost every torrent where the declivity is not great. By the efforts of this internal heat, the lava makes frequent explosions; its surface opens, and the liquid matter springs up and forms those masses which we see elevated above the level of the torrent. Le P. de la Torré, I believe, is the first person who observed this internal movement of burning lavas, which is always more violent in proportion to their thickness and the gentleness of the declivity. This effect is common to all matters liquified by fire, and every man may see examples of it in our common founderies *. If we observe those large ingots or masses of melted iron, which run in a mould or canal with a very small declivity, we shall perceive that they have a tendency to rise like arches, especially when the stream is very thick †. We have

* The lava of iron founderies exhibits the same effects. When this vitreous matter runs slowly, and accumulates at the base, we see eminences arise, which are bubbles or concave hemispheres of glass. These bubbles increase, when the expansive force is great, and the matter has little fluidity: it then suddenly explodes into a flame, and makes a considerable report. When the liquified matter is sufficiently adhesive to suffer a great dilatation, these superficial bubbles acquire a volume of eight or ten inches in diameter, without breaking. When the vitrification is less complete, and the matter is viscous and tenacious, the bubbles are smaller, and in cooling form concave eminences, called *toads' eyes.* What happens in miniature in our founderies, is likewise exhibited upon a larger scale in the lavas of volcanos.

† I have not mentioned some particular causes which frequently produce a curvature or swelling in our melted ingots: for example, when the matter is not very fluid, or when the

formerly shown, by experiments, that the time of consolidation is always proportioned to the thickness of the ingots, and that, when their surfaces are hardened, the interior parts still continue to be liquid. It is this internal heat which elevates the ingots and makes them blister. If their thickness were greater, there would be produced, as in the torrents of lava, explosions, ruptures in the surface, and perpendicular jets of metallic matter, pushed out by the action of the fire inclosed in the interior parts of the ingots. This explication, drawn from the nature of the thing itself, leaves no doubt concerning the origin of those eminences so frequent in valleys and plains, which have been overrun or covered with lava.

When, after descending from the mountain and traversing the fields, the burning lava arrives at the margin of the sea, its course is suddenly interrupted, the torrent advances, and, like a powerful enemy, makes the water at first retire: but the water by its immensity, by the resistance of its cold, and by its power of arresting and extinguishing fire, soon consolidates the torrent of burning matter, which can now proceed no farther, but rises up, accumulates new strata, and forms a perpendicular wall,

mould is too moist, the ingots bend considerably; because these causes concur in augmenting the effect of the first. Thus the humidity of the ground, on which the torrents of lava descend, and the internal heat, concur in raising the mass, and in producing explosions, which are always accompanied with those jets of matter formerly mentioned.

from the top of which the lava falls, and applies itself to the face of the wall thus formed. It is this falling and arresting of the burning matter that gives rise to basaltic prisms* and their jointed columns. These prisms have generally five, six, or seven sides, sometimes only three or four, and sometimes eight or nine. The basaltic columns are formed by the perpendicular fall of the lava into the sea, whether it falls from high rocks on the shore, or from a wall raised by its own accumulations. In both cases, the cold and humidity of the water arrest the burning matter, and consolidate its surfaces the moment it falls; and the successive bundles or masses of lava apply themselves to each other. As the internal heat of these masses tends to dilate them, a reciprocal resistance is created; and the same effect is produced as happens in the swelling of pease, or rather of cylindrical grain, when squeezed in a close vessel filled with boiling water. Each of these grains would assume a hexagonal figure by reciprocal compression. In the same manner, each bundle or mass of lava assumes several sides by dilatation and reciprocal resistance; and, when the resistance of the surrounding bundles is stronger than the dilatation of the bundle surrounded, instead of becoming hexagonal, it has only three, four, or five sides.

* I shall not here inquire into the origin of the term *basalt*, which M. Desmarets, of the Academy of Sciences, a learned naturalist, believes to have been applied by the ancients to different kinds of stones; but shall limit myself to the *basaltic lava*, which appears under the form of prismatic columns.

But, if the dilatation of the surrounded bundle is stronger than the resistance of the surrounding bundles, it assumes seven, eight, or nine sides, which are always longitudinal.

The transverse articulations of these prismatic columns are produced by a cause still more simple: the bundles of lava fall not in a regular and continued stream, nor in equal masses. Hence, if there are intervals in the fall of the matter, the superior surface of the forming column, being partly consolidated, is hollowed by the weight of the succeeding mass, which then moulds itself into a convex form in the concavity or depression of the first. This is the productive cause of those joints or articulations which appear in the greater part of prismatic columns. But, when the lava falls in an uninterrupted stream, then the basaltic column is one continued mass, without any articulations. In the same manner, when, by an explosion, some detached masses are darted from the torrent of lava, these masses assume a globular or elliptical figure, and are even sometimes twisted like cables. To this simple explication, all the forms of basalts and figured lavas may be easily referred.

It is to the rencounter of lava with the waves, and its sudden consolidation, that the origin of these bold coasts, which border all the seas at the foot of volcanic mountains, is to be ascribed. The ancient ramparts of basalt, found in the interior parts of continents, show that the sea has

been in the neighbourhood of these volcanos when they had thrown out lava. This is an additional proof of the ancient abode of the waters upon all the lands now inhabited.

The torrents of lava are from 100 to 2,000 and 3,000 fathoms broad, and sometimes 150, and even 200 feet thick: and, as we have found, by experience, that the time of the cooling of glass is to that of the cooling of iron as 132 to 236, and that the times of their respective consolidadation are nearly in the same proportion, it is easy to infer, that, to consolidate the thickness of ten feet of glass or lava, $201\frac{4}{5}\frac{1}{5}$ minutes would be necessary, since it requires 360 minutes to consolidate ten feet thick of iron, consequently it will require 4,028 minutes, or sixty-seven hours eight minutes, to consolidate 200 feet thick of lava: by the same rule, we shall find, that $30\frac{1}{2}\frac{1}{4}$ days, or a month, will be requisite before the surface of this lava of 200 feet thick be sufficiently cold to admit of being touched. Hence a year will be necessary to cool a lava of 200 feet thick, so as to admit of being touched, without burning, at the depth of one foot; and, at ten feet deep, it will be still so warm, at the end of ten years, as not to be tangible; and 100 will be requisite to cool it to the same degree in the middle of its thickness. Mr. Brydone relates, that, more than four years after the lava had flowed, in the year 1766, at the foot of Ætna, it was not perfectly cool. Massa, a Sicilian author worthy of credit, tells us, "that,

being at Catania, eight years after the great eruption in 1669, he found, that the lava in several places was not entirely cool*."

About the end of April, 1771, sir William Hamilton dropt pieces of dry wood into a crevice in the lava at Vesuvius, and they were instantly inflamed: the lava issued from the mountain on the 19th of October, 1767, and had no communication with the fire of the volcano. The place where this experiment was made was at least four miles distant from the mouth from which the lava issued. He is firmly persuaded, that many years are necessary to cool a lava of this thickness (about 200 feet).

I have had no opportunity of making experiments upon consolidation and cooling, but with balls of some inches in diameter. The only method of making experiments on a larger scale would be, to observe lavas, and to compare the times exhausted in their consolidation and cooling, according to their different thicknesses. I am satisfied that these observations would confirm the law I have established for the cooling of bodies from the state of fusion to the common temperature; and, although these new observations are by no means necessary to support my theory, still they would help to fill up that immense gap between a cannon ball and a planet.

It now remains for us to examine the nature of lava, and to show, that, in time, it is con-

* Voyage au Sicile, tom. i. p. 213.

verted into fertile earth; which recalls the idea of the first conversion of the scoriæ of the primitive glass that covered the whole surface of the globe after its consolidation.

" Under the denomination of lava, we comprehend not," says M. de la Condamine, " all the matter thrown out by a volcano, such as ashes, pumice stones, gravel, and sand; but solely those reduced to a liquid state by the action of fire, and which, by cooling, form solid masses, whose hardness surpasses that of marble. This restriction notwithstanding, many other species of lava may be conceived, according to the different degrees of fusion in the mixture, the greater or smaller quantity of metal, and its greater or lesser intimate union with the various matters. Beside many intermediate kinds, three species are easily distinguishable. The purest lava resembles, when polished, a stone of an obscure dirty gray colour. It is smooth, hard, heavy, and interspersed with small particles similar to black marble, and whitish points. It seems to contain metallic particles. At first sight, it resembles serpentine, when the colour of the lava does not tend to green. It receives a pretty fine polish, which is more or less vivid in different parts. It is made into tables, chimney-pieces, &c.

" The coarsest kind of lava is rugged and uneven. It resembles the scoriæ or dross of iron. The most common species holds a middle rank between the two extremes: it is that which we every where find in large masses upon the sides

of Vesuvius and in the adjacent fields, where it has run in torrents. In cooling, it has formed masses similar to ferruginous and rusty rocks, which are often many feet thick. These masses are frequently interrupted and covered with ashes and calcined matter. . . . . . It is under several alternate strata of lava, ashes, and earth, the whole of which forms a crust of from sixty to eighty feet thick, that temples, porticos, statues, a theatre, and an entire city have been discovered*."

M. Fougeroux de Bondaroy remarks, "that, immediately after an eruption of burnt earth or of a kind of ashes, Vesuvius generally throws out lava, which runs down the fissures or furrows made in the mountain. . . .

"The mineral matter inflamed, melted, and flowing, or lava, properly so called, issues through cracks or crevices with more or less impetuosity, and in greater or smaller quantity, according to the violence of the eruption. It spreads to a greater or smaller distance, according to the degree of fluidity, and the declivity of the mountain, which more or less retards its cooling. . . . .

"That which now covers a part of the land at the foot of the mountain, and which sometimes stretches as far as Portici, consists of large heavy masses, bristled with points on their upper surface. The surface which rests on the ground is flatter: as these pieces lie above

* Mem. de l'Acad. des Sciences, ann. 1757, p. 374.

each other, they have some resemblance to the waves of the sea. When the pieces are larger and more numerous, they assume the figure of rocks. . . . .

"In cooling, the lava effects various forms. . . . The most common is that of tables or boards, of greater or smaller dimensions. Some pieces are six, seven, and eight feet long. It breaks into this form in cooling and consolidating. This is the species of lava which is bristled with points. . . . . .

"The second species resembles great ropes: it is always found near the mouth of the volcano, and appears to have been suddenly fixed, and to have rolled before it hardened. It is lighter, more brittle, more bituminous, and softer, than the first species. By breaking it, we likewise perceive that its substance is not so close and compact. . . .

"At the top of the mountain, we find a third species of lava, which is brilliant, and composed of threads, which sometimes cross one another. It is coarse, and of a reddish violet colour. . . . . Some fragments are sonorous, and have the figure of stalactites. . . . . . Lastly, in certain parts of the mountain, we find lavas of a spherical form, and appear to have been rolled. It is easy to conceive how the figures of these lavas might be varied by a number of accidental circumstances*," &c.

Matter of every kind enters the composition

* Mem. de l'Acad. des Sciences, ann. 1766, p. 75.

of lavas. Iron and a small quantity of copper have been extracted from the lava found on the summit of Vesuvius. Some specimens are so impregnated with metallic substances as to preserve the flexibility of metal. I have seen two large tables of lava, of two inches thick, which were polished like marble, and bended with their own weight. I have seen others, which were bended by a weight, and resumed their horizontal position by their own elasticity.

All lavas, when reduced to powder, are, like glass, susceptible of being converted, by the intervention of water, first into clay, and afterwards, by the mixture of dust and corrupted vegetables, into excellent soil. These facts are apparent from the vast and beautiful forests which surround Ætna, and grow upon a bottom of lava, covered with several feet of good earth: the ashes are more quickly converted into earth than the powder of glass or of lava. In the craters of old extinguished volcanos, as well as on the ancient rivers of lava, we find very fertile soils. Hence the devastations occasioned by volcanos are limited by time; and, as Nature is always more disposed to produce than to destroy, she, in a few ages, repairs the devastations of fire, and restores to the earth its former fertility by the very same materials she had employed for the purposes of destruction.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVII.

Of new Islands, Caverns, perpendicular Fissures, &c.

NEW islands are formed in two ways, either suddenly, by the operation of subterraneous fires, or slowly, by the accumulated sediments of water. Upon this subject we are furnished with indubitable facts, both by ancient historians, and by modern voyagers. Seneca tells us, that, in his time, the island of Therasia * suddenly emerged from the sea, to the astonishment of many spectators. Pliny relates, that thirteen islands formerly arose all at once from the bottom of the Mediterranean, and that Rhodes and Delos are the chief of them. According to Ammianus, Marcellinus, Philo, Pliny, &c., these thirteen islands were not formed by an earthquake or by a subterraneous explosion, but were formerly concealed under the water, which sunk and un-

* Now called Santorini.

covered them. Delos was even distinguished by the name of Pelagia, because it formerly belonged to the sea. Whether these thirteen new islands were produced by the action of subterraneous fire, or by any other cause which diminished the quantity of water in the Mediterranean, it is not easy to determine. But we are informed, by Pliny himself, that the island of Hiera, in the neighbourhood of Therasia, is composed of ferruginous masses, and of earth which had been thrown up from the bottom of the sea; and, in another place, he mentions several other islands which had been formed in the same manner. Upon this subject, however, we have facts more recent, and less involved in obscurity.

On the 23d day of May, 1707, at sun-rising, there appeared, at the distance of two or three miles from the island of Therasia or Santorini, something which had the resemblance of a floating rock. Some men, stimulated by curiosity, approached it, and discovered that it had arisen from the bottom of the sea; that it increased under their feet; that oysters, and other shells, still adhered to the rocks; and that many pumice stones lay on its surface. Two days before this rock appeared, there had been a slight earthquake in Santorini. This island continued to augment considerably, without any accident, till the 14th of June. It was then about half a mile in circumference, and twenty or thirty feet high, and the earth was white and mixed with clay. After this time, the sea began to be more and

more agitated; vapours arose from it, which infested the island of Santorini, and, on the 16th of July, seventeen or eighteen rocks rose all at once from the bottom of the sea, and united into one mass. These phænomena were attended with a frightful noise, which continued two months; and flames issued from the new island, which still augmented, both in circumference and height; and the explosions were so violent, that they drove large stones to more than seven miles distance. The island of Santorini itself was regarded by the ancients as a recent production: and, in 726, 1427, and 1573, it received considerable additions, beside the small islands formed in its neighbourhood*. The same volcano, which, in the days of Seneca, raised the island of Santorini, produced, in Pliny's time, that of Hiera or Volcanella, and, in our days, the rock above described.

On the 10th of October, 1720, a great fire was seen to arise from the sea near the island of Tercera. Navigators being sent, by order of government, to examine it, they perceived, on the 19th of the same month, an island covered with fire and smoke; and a prodigious quantity of ashes was thrown to a great distance, as from a volcano, and accompanied with a noise similar to that of thunder. The earth was also perceived to shake in the neighbourhood; and a vast number of pumice stones were found floating on the

* See l'Hist. de l'Acad. des Sciences, 1708, p. 23.

sea all round the new island: this last phænomenon has sometimes been remarked in the open sea *.

The historian of the French Academy †, in relating this event, remarks, that, after an earthquake in the island of St. Michael, one of the Azores, there appeared a torrent of fire between this island and that of Tercera, which gave rise to two new rocks: and, in the subsequent year, the same historian gives the following detail:

" M. de l'Isle has informed the Academy of several particulars concerning the new island among the Azores, which he received in a letter from M. de Montagnac, consul at Lisbon. On the 18th of September, 1721, M. de Montagnac's vessel was moored off the fortress of St. Michael; and he learned the following particulars from the pilot of the port:

" During the night of the 7th or 8th of December, 1720, there was a great earthquake in Tercera and St. Michael, which islands are distant from each other about twenty-eight leagues, and a new island rose from the sea. It was, at the same time, remarked, that the point of the island of Peak, at the distance of thirty leagues, which formerly threw out flames, was extinguished. But a continual thick smoke issued from the new island, which was distinctly perceived by M. de Montagnac, as long as he

* See Phil. Trans. abridg. vol. vi. part ii. p. 154.

† Ann. 1721, p. 26.

continued in that part. The pilot assured him, that he had sailed round the island, and approached it as near as he could with safety. He sounded on the south side of it with a rope of sixty fathoms, but found no bottom. On the west side, the water was much changed: it appeared to be mixed with white, blue, and green; and, at the distance of two miles, it seemed to be shallow and boiling On the north-west, the side from which the smoke issued, he found, at fifteen fathoms, a bottom of coarse sand. He threw a stone into the sea, and, at the place where it fell, he observed the water boil, and mount into the air with great impetuosity. The bottom was so hot, that, at two different times, it melted a piece of suet which had been fastened to the end of the plumb-line. The pilot likewise remarked, that smoke issued from a small lake, in the midst of a sandy plain. This island is nearly round, and high enough to be perceived, in clear weather, at the distance of seven or eight leagues.

"We have since learned, by a letter from M. Adrien, French consul at St. Michael, dated in March, 1722, that the new island is considerably diminished: that it is nearly on a level with the water; and that it will probably soon disappear."

From these, and many other facts of a similar nature, it is apparent that inflammable bodies exist under the bottom of the sea, and that they sometimes produce violent explosions. The

places where they happen may be considered as submarine volcanos, which differ from common volcanos only in the shorter duration of their effects; for, after the fire opens a passage to itself, the water rushes in, and extinguishes them. The elevation of new islands necessarily leaves caverns, which are soon filled by the waters; and the new ground, which consists of matter thrown out by the submarine volcano, must, in every respect, resemble that of the Monti di Cinere, and other eminences which have been raised by terrestrial volcanos. It is on account of the waters rushing into the voids and fissures produced by explosions, that submarine volcanos exhibit their effects less frequently than common volcanos, though both derive their origin from the same cause.

To subterraneous, or rather submarine fires, must be ascribed all those ebullitions of the sea, and water spouts, which have been remarked in different places by mariners: they also produce storms and earthquakes, the effects of which are felt equally at sea as upon land. The islands raised by submarine volcanos are generally composed of pumice stones and calcined rocks.

Fire has frequently been observed to issue out of the waters of the sea. Pliny tells us, that the whole surface of the Thrasymen Lake has appeared to be inflamed; and Agricola informs us, that, when a stone was thrown into the lake of Denstat in Thuringia, its descent was marked by a train of fire.

Lastly, The great quantities of pumice stones

discovered by voyagers in different parts of the ocean, as well as in the Mediterranean, evince the existence of volcanos in the bottom of the sea, which differ not from those upon land, either in the violence of their explosions, or in the matter they throw out, but only in their rarity, and in the shortness of their duration. Hence it may be remarked, that the bottom of the sea every way resembles the surface of the earth, not admitting even the exception of volcanos.

Between sea and land volcanos there are many relations. Both of them exist on the tops of mountains. The Azore islands, and those of the Archipelago, are only the points of mountains, some of which are above, and others under, the surface of the water. From the account of the new islands among the Azores, it appears that the place where the smoke issued was only fifteen fathoms deep, which, when compared with the ordinary depth of the ocean, demonstrates this place to be the top of a pretty high mountain. The same remark may be made with regard to the new island near Santorini. Its depth must have been inconsiderable, since oysters were found attached to the rocks which rose above the surface of the water. It likewise appears, that sea volcanos, as well as those upon land, have subterraneous communications; for, at the very time that the new island among the Azores arose, the summit of the volcano of St. George, in the island of Peak, sunk. It also merits observation, that new

islands never appear but in the neighbourhood of old ones; and that there are no examples of new islands in open seas: they ought, therefore, to be regarded as continuations of the ancient islands; and, when volcanos happen to exist in the latter, it is not surprising that the former should contain the same materials, which may be kindled either by fermentation alone, or by the action of subterraneous winds.

Besides, new islands produced by earthquakes, or by subterraneous fires, are few in number. But the number of those formed by slime, sand, and earth, transported by rivers, or by the motions of the sea, is almost infinite. At the mouths of rivers, such quantities of earth and sand are amassed, as frequently give rise to islands of considerable extent. The sea, by retiring from certain coasts, leaves uncovered the highest parts of the bottom, and these parts constitute so many new islands. In the same manner, when the sea encroaches upon the land, it covers the plains, and the more elevated grounds appear in the form of islands. It is for this reason that there are few islands in the open seas, and that they are so numerous near the coasts.

Fire and water, though of very opposite natures, exhibit many effects so similar, that the one may often be mistaken for the other. Beside the productions peculiar to these elements, as crystal, glass, &c., they give rise to many great phænomena, which have such strong resemblances, that they can hardly be distinguished. Water, as we have seen, elevates mountains,

and forms the greatest number of islands: some mountains and islands likewise derive their origin from fire. The same observation is applicable to caverns, fissures, gulfs, &c. Some of them are the effects of fire, and others of water.

Caverns are, in a great measure, peculiar to mountains: they are seldom or never found in plains. They are frequent in the Archipelago, and other islands; because islands are generally nothing but the tops of mountains. Caverns, like precipices, are formed by the sinking or mouldering of rocks, or, like abysses, by the action of fire; for, to make a cavern form a precipice or an abyss, nothing farther is necessary than that the tops of the opposite rocks should come together and form an arch, which must frequently happen when they are loosened at the root, and shaken by earthquakes, or by the operation of time and of the weather. Caverns may be produced by the same causes which give rise to gulfs, apertures, or sinkings of the earth; and these causes are explosions of volcanos, the action of subterraneous vapours, and earthquakes, which create such commotions in the earth, as must necessarily produce caverns, fissures, and hollows of every kind.

The cavern of St. Patrick in Ireland is not so considerable as it is famous: the same remark may be made with regard to the Grotto del Cane in Italy, and to that of Mount Beniguazeval, in the kingdom of Fez, which throws out fire. There is a very large cavern in the county of Derby in England. It is much larger

than the celebrated cavern of Bauman, near the Black Forest of Brunswick. I was informed by the earl of Morton, a philosopher more respectable for his merit than his high rank, that the entrance to this cavern, called the Devil's Hole, is larger than the door of any church; that a small river runs through it; that, after advancing some way, the vault of the cavern sinks down so low, that, in order to proceed farther, it is necessary to lie flat in a boat, and to be pushed through this narrow passage by people accustomed to the business; and that, after getting through, the roof, or arch of the cavern, rises to a great height; and, after walking a considerable way on the side of the river, the arch sinks again so low as to touch the surface of the water. Here the cavern terminates. The river, which seems to have its source in this part of the cavern, swells occasionally, and transports heaps of sand, which, by accumulating, forms a kind of blind alley, whose direction is different from that of the principal cavern.

In Carniola, near Potpechio, there is a large cavern, in which is a pretty considerable lake. Near Adelsperg, we meet with a cavern in which a man may travel two German miles. It contains several tremendous and deep precipices*. The Mendip hills in Somersetshire likewise present us with extensive caverns, and very fine grottos. Near these caverns we find veins of lead, and sometimes large oak trees, buried fifteen fathoms

* See Acta erud. Lips. anno 1689, p. 551.

deep. In the county of Gloucester, there is a large cavern called Pen-park-hole, at the bottom of which we meet with thirty-two fathoms of water. Here are also veins of lead.

It is apparent that the Devil's Hole, and other caverns, from which large springs or brooks issue, have been gradually formed by the operation of the water, and their origin cannot be ascribed to earthquakes or volcanos.

One of the largest and most singular caverns we are acquainted with, is that of Antiparos, of which M. Tournefort has given a complete description. We first find a rustic cave about thirty feet wide, divided by some natural pillars. Between two pillars on the right, the ground slopes gently, and then more precipitately for about twenty paces to the bottom of the cavern. This is the passage to the grotto or interior cave, and is nothing but a dark hole, through which a man cannot pass without stooping and the assistance of lights. We then descend, by means of a rope fixed at the entrance, a horrible precipice, and arrive on the borders of another still more tremendous, with corresponding abysses on the left. By a ladder placed on the margin of these gulfs, we get over a vast perpendicular rock. We then continue to slip through places less dangerous. But, when we think ourselves in the greatest safety, we are suddenly stopped by a frightful pass; to escape through which, we are obliged to glide on our backs along a large rock, and to descend by means of a ladder. When we arrive at the bottom of the ladder, we

stumble for some time among irregular rocks, and then the famous grotto presents itself. This grotto is about 300 fathoms below the surface of the earth, and it appears to be about forty fathoms high, and fifty wide. It is full of large and beautiful stalactites, which both depend from the roof of the vault and cover the floor*.

In that part of Greece called Achaia by the ancients, now Livadia, there is a large cavern in a mountain which was formerly famous for the oracles of Trophonius: it is situated between the lake of Livadia and the sea, from which, at the nearest part, it is distant about four miles; and there are no less than forty subterraneous passages, through which the waters run under the mountain†.

In all countries which are subject to earthquakes or volcanos, caverns are frequent. The structure of most of the islands of the Archipelago is exceedingly cavernous. The islands in the Indian Ocean, and particularly the Moluccas, appear to be chiefly supported upon vaults. The land of the Azores, of the Canaries, of the Cape de Verd islands, and, in general, of almost all small islands, is, in many places, hollow, and full of caverns; because these islands, as formerly remarked, are only the tops of mountains, which have suffered great convulsions either from volcanos, or by the action of the waters, of frosts,

* See Tournefort's Voyage to the Levant.

† See Gordon's Geography, p. 179.

and of other injuries of the weather. In the Cordeliers, where volcanos and earthquakes are frequent, there are many caverns, precipices, and abysses.

The famous labyrinth in the island of Crete, is not the work of nature alone. We are assured by M. Tournefort, that, in many parts of it, the operation of men is evident; and, it is probable, that this is not the only cavern which has been augmented by art. Mines and quarries are constantly digging; and after these have been long deserted, it is not easy to determine whether such excavations have been the effects of nature or of art. Some quarries are amazingly extensive. That of Maestricht, for instance, is sufficient to shelter 50,000 men, and is supported by more than 1,000 pillars of twenty feet high; and the earth and rock above is twenty-five fathoms thick*. The salt mines of Poland exhibit excavations still more extensive. Near large cities, quarries and artificial hollows are common. But we must proceed no farther in detail. Besides, the operations of men, however great, will always make but an inconsiderable figure in the history of nature.

In my Theory of the Earth, I mentioned only two kinds of caverns, the one produced by the fire of volcanos, and the other by the motion of subterraneous waters. Those two species of caverns are not situated at great depths.

* See Phil. Trans. abridg. vol. ii. p. 463.

They are even new, when compared with those vast cavities, which were formed at the time the globe first assumed a solid form; for, at this period, all the superficial eminences and hollows, and all the cavities in the interior parts of the earth, especially near the surface, were produced. Several of those caverns, produced by the primitive fire, after being supported for some time, have afterwards split by cooling, which diminishes the volume of every kind of matter; these would soon fall in, and, by their sinking, form basins or reservoirs for the sea, into which the waters, formerly much elevated above this level, ran, and abandoned the lands which they originally covered. It is more than probable, that a certain number of these ancient caverns still subsist in the interior parts of the globe, and, by their sinking, may produce similar effects, and give rise to new receptacles to the waters. In this case, they will partly abandon the basin which they now occupy, and run, by their natural propensity, into these lower places. For example, we find beds of sea shells in the Pyrennees 1,500 fathoms above the present level of the ocean. Hence it is certain, that the waters, when these shells were formed, rose 1,500 fathoms higher than they do at present. But, when the caverns, which supported the lands that are now the bed of the Atlantic Ocean, sunk, the waters which covered the Pyrennees, and the whole of Europe, would run with rapidity into these reservoirs, and, of course, leave uncovered all the lands in this part of the world.

The same revolution would extend to every other country. The water appears to have never reached the summits of the highest mountains, because they exhibit no relics of marine productions, and no sufficient marks of a long abode of the waters. However, as some of the matters of which they are composed, though all of the vitrescent kind, seem to have derived their solidity and consistence from the intervention and cement of water, and as they appear to have been formed, as already remarked, in the masses of sand, or glass dust, which formerly lay on the peaks of mountains, but which, in the progress of time, have been carried down to their bottoms by the rains, we cannot pronounce positively, that the waters of the sea never stood higher than the places where shells are now found: the waters have perhaps stood much higher, even before their temperature permitted the existence of shells. The greatest height reached by the universal ocean is to us unknown. But we know that the waters were elevated from 1,500 or 2,000 fathoms above their present level; since shells are found in the Pyrennees at 1,500 fathoms, and in the Cordeliers at 2,000.

If all the peaks of mountains were formed of solid glass, or of other matters immediately produced by fire, it would be unnecessary to have recourse to the abode of the waters, or to any other cause, in order to conceive how they assume their consistence. But most peaks of mountains seem to be composed of matters,

which, though vitrifiable, have acquired their solidity by the intervention of water. We cannot, therefore, determine whether their consistence is solely owing to the primitive fire, or whether the intervention and cement of water were not requisite to complete the operation of fire, and to bestow on these vitrifiable masses the qualities which they possess. Besides, this supposition prevents not the primitive fire, which at first produced the greatest inequalities on the globe, from being the chief cause of those chains of mountains that traverse its surface, and particularly of their cores or nuclei; but the contours of these same mountains have perhaps been disposed and fashioned by the waters at a subsequent period; for it is upon these contours, and at certain heights, that shells and other productions of the sea are found.

To acquire a clear notion of the ancient caverns formed by the primitive fire, we must suppose the globe to be deprived of all its waters, and of all the matters which cover its surface, to the depth of 1,000 or 1,200 feet. By removing in idea this external bed of earth and water, the globe will present to us the form it possessed about the time of its first consolidation. The whole mass was composed of vitreous rock, or, if you will, of melted glass; and this matter, in cooling and acquiring consistence, produced, like all other melted bodies, eminences, depressions, and cavities, upon the whole surface of the globe. These internal cavities, formed by

fire, are the primitive caverns, and they are more numerous in the southern than in the northern regions; because the rotatory motion, which elevated the equatorial regions before consolidation, likewise produced the greatest derangement of the matter, and, by retarding the consolidation, would concur with the action of the fire in giving rise to a greater number of inequalities in this than in any other part of the globe. The waters coming from the poles could not approach those burning regions before they cooled. The vaults which supported these regions have successively fallen in, the surface sunk and broke in a thousand places. For this reason, the greatest inequalities of the globe are found in the equatorial regions. There the primitive caverns are more numerous than in any other part of the earth. They are likewise more profound, *i. e.*, perhaps five or six leagues deep; because the matter of the globe, while in a liquid state, was agitated to that depth by the motion of rotation. But all the caverns in high mountains derive not their origin from the operation of primitive fire. Those alone which are deeply situated below the mountains can be ascribed to this cause. The more exterior and more elevated have been formed, as already remarked, by the operation of secondary causes. Hence the globe, deprived of its waters and the matters transported by them, would present to us a surface much more irregular than it appears with the aid of this covering. The great chains of moun-

tains, and their peaks and ridges, have not now the appearance of half of their real height. The whole are attached by their bases to a vitrifiable rock, and are of the same nature. Thus we should reckon three species of caverns produced by nature: the first by the force of the primitive fire; the second by the action of water; and the third by that of subterraneous fires: each of these caverns, though different in their origin, may be distinguished by examining the matters they contain, or by which they are surrounded.

Volcanos and water, which form caverns in the bowels of the earth, produce likewise on its surface fissures, precipices, and abysses. At Cajeta in Italy, there is a mountain which had been formerly split by an earthquake in such a manner, that the separation seems to have been made by the hands of men. We have already mentioned the Wheel-track, or great fissure in the island of Machian, the abyss of Mount Ararat, the port or gap in the Cordeliers, that of Thermopylæ, &c. To these we might add the gap in the mountain of the Troglodites in Arabia, and that of the Ladders in Savoy, which was begun by nature, and finished by Victor-Amadæus. Considerable sinkings in the earth, the fall of rocks, and the subversion of mountains, are frequently produced by the waters, as well as by subterraneous fires. Of this many examples might be given.

" In the month of June, 1714, a part of the mountain of Diableret in Valois fell suddenly,

and, in a few hours, the sky being serene, it appeared to have assumed a conical figure. It destroyed fifty-five houses, besides several men, and a great many cattle; and it covered a league square with its ruins. The sky was darkened with the dust: the collection of stones and earth, which were amassed on the plain, exceeded thirty Rhenish perches in height, dammed up the waters, and gave rise to new lakes of considerable depths. But this phænomenon was not accompanied with the least vestige of bitumen, sulphur, or calcined lime-stone; nor, consequently, of subterraneous fire: the base of this great rock appeared to be rotten, and reduced to powder*."

There is a remarkable example of these sinkings near Folkstone in the county of Kent. The hills in the neighbourhood sunk insensibly, without any earthquake or other commotion. The interior parts of these hills consist of rocks and chalk; and, by their sinking, they have pushed part of the adjacent land into the sea. A well attested relation of this fact may be seen in the Philosophical Transactions †.

In 1618, the town of Pleurs was buried under the rocks at the foot of which it had been situated. In 1678, a great inundation was occasioned, in Gascony, by the sinking of some portions of one of the Pyrennees, which forced out the water that had been pent up in the subterraneous caverns of these mountains. In the

* Hist. de l'Acad. des Sciences, ann. 1715, p. 4.

† Abridg. vol. iv. p. 250.

year 1680, a still greater inundation was produced in Ireland, by the sinking of a mountain into caverns which had been full of water. It is not difficult to investigate the cause of these effects. It is well known, that subterraneous waters are every where frequent. These waters gradually work away sand and earth in their passages; and, consequently, they may, in the course of time, destroy the stratum of earth which serves as a basis to the mountain: if this stratum fail more on one side than on another, the mountain must, of necessity, be overturned; or, if the base wastes gradually and equally throughout, the mountain will sink, without being overturned.

Having mentioned a few of those convulsions and changes produced in the earth by what may be called the accidents of nature, we must not pass over in silence the perpendicular fissures in the different strata. These fissures are obvious, not only in all rocks and quarries, but in clays, and in every species of earth which has never been removed from its natural position. They are called perpendicular fissures; because, like the horizontal strata, they are never oblique, but from some accidental change. Woodward and Ray talk of fissures, but in a general and confused manner, and they never mention them under the appellation of perpendicular fissures, because they imagined that they might be indifferently either oblique or perpendicular. No author has hitherto attempted to explain their origin, though it is apparent, as remarked in a former article,

that they have been occasioned by the drying of the materials which compose the horizontal strata. In whatever manner this drying should happen, perpendicular fissures must have been a necessary consequence; for the matter of the horizontal strata could not be diminished in size, without splitting, at different distances, in a direction perpendicular to the strata themselves. Under perpendicular fissures, I comprehend, not only the natural cracks in rocks, but all those separations which have been effected by convulsive accidents. When a mass of rock has suffered any considerable motion, the fissures are sometimes placed obliquely; but it is because the mass itself is oblique; and the smallest attention to quarries of marble and lime-stone, or to great chains of rocks, will convince us, that the general direction of fissures is perpendicular to the strata in which they are found.

The bowels of mountains are chiefly composed of parallel strata of stones and rocks. Between the parallel strata, we often meet with beds of matter softer than stone; and the perpendicular fissures are filled with sand, crystals, metals, &c. The formation of these last bodies is more recent than that of the horizontal strata in which sea shells are found. The rains have gradually detached the sand and earth from the tops of mountains, and left the stones and rocks bare, which afford an opportunity of distinguishing with ease both the parallel strata and the perpendicular fissures. On the other hand, the rains and rivers have successively covered the

plains with considerable quantities of earth, sand, gravel, and other bodies which are either soluble in, or easily divisible by water. Of these have been formed beds of tufa, of soft stone, of sand, of rounded gravel, and of earth mixed with vegetable substances. But these beds contain no sea shells, or, at most, but fragments of them, which have been detached from the mountains along with the earth and gravel. These recent beds should be carefully distinguished from the ancient and original strata, in which we almost universally find a great number of entire shells placed in their natural situation.

In examining the internal order and distribution of the materials of a mountain, composed of common stone or calcinable lapidific matter, we generally find, after removing the vegetable soil, a bed of gravel, of the same nature and colour with the stones which predominate in the mountain; and, under the gravel, we meet with the solid rock. When the mountain is cut by a deep trench or ravine, the different banks or strata are easily distinguishable. Each horizontal stratum is separated by a kind of joint or suture, which is likewise horizontal. These strata generally augment in thickness, in proportion to their depth or distance from the top of the mountain; and they are all divided, vertically, by perpendicular fissures. In general, the first stratum under the gravel, and even the second, are not only thinner than those which form the base of the mountain, but so much cut by per-

pendicular fissures, that small portions of them only have any coherence. Most of these fissures, which exactly resemble the cracks in earth that has been dried, gradually disappear as they descend, and, at the base of the mountain, where they cut the larger strata in a more regular and more perpendicular manner than those near the surface, their number is much smaller.

These strata of rock often extend, without interruption, to great distances. Stones of the same species likewise are almost uniformly found in opposite mountains, whether they be separated by a narrow neck or a valley; and the strata never entirely disappear, unless when the mountain terminates in a large and level plain. Sometimes we find, between the vegetable soil and the gravel, a stratum of marl, which communicates its colour, and other qualities, to the neighbouring beds: the perpendicular fissures in the inferior rocks are, in this case, filled with marl, where it acquires a hardness equal, in appearance, to that of the surrounding stone; but, when exposed to the air, it splits, and becomes soft and ductile.

The beds of stone which compose the tops of mountains are generally soft and tender, but those near the base are exceedingly hard. The first is commonly white, and of a grain so fine as to be hardly perceptible. In proportion as they descend, the rocks become more compact, and have a better grain; and the lowest beds are not only harder than the superior ones, but are also

more compact and heavy. Their grain is fine and brilliant; and they are often so brittle as to break as purely and neatly as flint.

The heart of a mountain, then, is composed of different strata of stones, which are harder or softer in proportion to their distance from the summit; and they are broad at the bâse, and sharp and narrow at the top. The last is, indeed, a necessary result of the first: for, as the stones grow harder as they descend, it is natural to think, that the currents, and other motions of the water, which scooped out the valleys, and formed the contours of the mountains, must have gradually consumed, by their lateral friction, the materials of which the mountains are composed; and that this consumption would be proportioned to the hardness or softness of the matter acted upon. But, as the upper strata are known to be softest, and as their density increases according as they approach the base, the mountains must, of necessity, have assumed their present inclined, and somewhat conical figure. This is one great cause of the declivity of mountains; and it must always become more gentle, in proportion as the earth and gravel are brought down by the rain from their summits. For these reasons, the declivity of hills and mountains, composed of calcinable bodies, is less than that of those which consist of granite, or of flint in large masses. The latter generally rise almost perpendicularly to very great heights; because in these masses of vitrifiable matter, the superior, as well as the inferior strata,

are extremely hard, and have presented nearly an equal resistance to the operation of the waters.

Though, in the tops of some hills which are flat, and pretty extensive, we find hard stone immediately under the vegetable soil; yet it should be remarked, that, in every example of this kind, what appears to be the summit of a hill is only a continuation of some more elevated hill in the neighbourhood, the upper strata of which consist of soft, and the inferior strata of hard stone; and the hard stone found on the top of the first hill is only a continuation of the under strata of the higher hill.

Still, however, on the tops of hills which are not surmounted by higher grounds, the stone is mostly of a soft and friable nature; and hard stone cannot be had without digging to a considerable depth. It is between these layers of hard stone only that marble is to be found; and it is variegated with different colours by metallic substances carried down by rain-water, and filtrated through the strata: and it is probable that, in every country which furnishes stones, marble would be found, if pits were dug to a sufficient depth: "Quoto enim," says Pliny, "loco non suum marmor invenitur?" It is, in fact, a more common stone than is generally imagined, and differs from other stones only in the fineness of its grain, which renders it compact, and susceptible of a fine and brilliant polish.

Both the perpendicular fissures, and the horizontal joints of quarries, are often filled, or encrusted, with concretions, which are sometimes

transparent, and of regular figures, as crystals, and sometimes earthy and opaque. Water runs through the perpendicular fissures, and even penetrates the close texture of the stone itself. Stones which are porous imbibe water so copiously, that frost splits them in pieces. The rain-waters, by filtrating through different strata, are impregnated with a great variety of substances. They first sink through the perpendicular fissures; they then penetrate the strata of stone, and deposit, in the horizontal joints, as well as in the perpendicular fissures, such matter as they collect in their course, and give rise to different concretions, according to the nature of these substances. For example, when the water filtrates through marl, clay, or soft stone, the matter which it deposits is nothing but a fine, pure marl, and commonly appears in the perpendicular fissures under the form of a porous, soft, white, light substance, known among naturalists under the name of *Lac Lunæ*, or *Medulla Saxi*.

When veins of water, charged with stony matter, run along the horizontal joints of soft stone or chalk, this matter adheres to the surface of the stones, and forms a white, scaly, light, and spongy crust, which, from its resemblance to the agaric, has been called *mineral agaric*. But if the strata through which the water penetrates be hard stone, the filter being closer, the water it allows to pass will be impregnated with a stony matter more pure and homogeneous; and, consequently, the particles, being capable of a

more compact and intimate union, will form concretions, nearly of equal density with the stone itself, and somewhat transparent. In quarries of this kind, the stones are encrusted with undulated concretions, which entirely fill up the horizontal joints.

In grottos and cavities of rocks, which may be regarded as the basins or common sewers of the perpendicular fissures, the different directions of the veins of water give different forms to the concretions that result from them. These forms are generally wreathed, or resemble an inverted cone, attached to the roof of the cavern; or, rather, they are white, hollow cylinders, composed of concentric coats. The impregnated waters sometimes fall in drops upon the floor of the cavern, and form columns, and a thousand whimsical figures, to which naturalists have given the different appellations of *stalactites*, *stalagmites*, *osteocollæ*, &c.

Lastly, When the concreting juices issue immediately from marble, or very hard stone, the lapidific matter is rather dissolved than suspended in the water, and it forms a kind of columns with triangular points, which are transparent, and consist of oblique coats. This substance is distinguished by the name of *spar* or *spalt*. It is transparent and colourless, except when the stone or marble through which it filtrates contains metallic particles. This spar is of equal hardness with the stone itself, and it dissolves in acids, and calcines with the same degree of heat. Hence it is evident, that spar is a true stone, and

perfectly homogeneous. It may even be considered as a pure and elementary stone.

Most naturalists, however, consider this as a distinct substance, existing independent of stone: it is the lapidific or crystalline juice, which, in their estimation, not only cements the particles of common stone, but even those of flint. This juice, they allege, daily augments the density of stones by reiterated filtrations, and at last converts them into flint: when concreted into spar, it perpetually receives fresh supplies of still purer juice, which increases both its hardness and its density, till it changes to the consistence of glass, then to that of crystal, and at last it is converted into genuine diamond.

But, on this supposition, Why does the lapidific juice produce stone in some provinces only, and nothing but flint in others? It may be said, that the one province is less ancient than the other, and that the juice has not had time sufficient to complete its natural operations. But in this there is not the shadow of probability. Besides, from whence does this juice proceed? If it gives rise to stones and flints, from whence does it derive its own origin? It is obvious, that it has no existence independent of those substances which alone can impart to the water that penetrates them a petrifying quality, that uniformly corresponds with their nature and peculiar properties. Thus when it filtrates through stone, it produces spar; when it issues from flint, it forms crystal; and there are as many species of this

juice as of bodies from which it proceeds. Experience confirms this account of the matter. The waters which filtrate through quarries of common stone form tender and calcinable concretions similar to the stones themselves. On the other hand, the waters which exude from granite or from flint, produce concretions hard and vitrifiable, and they have all the other properties of flint, as the former had all those of stone. In the same manner, the waters, which filtrate through mineral and metallic substances, give rise to pyrites, marcasites, and metallic grains.

It was formerly remarked, that all matter might be divided into the two great classes of vitrifiable and calcinable. Clay and flint, marl and stone, may be regarded as the two extremes of each class, the intervals between which are filled with an almost infinite variety of mixts, that have always one or other of these substances for their basis.

The substances belonging to the first class can never acquire the properties of those of the latter. Stone, however ancient, will for ever be equally removed from the nature of flint, as clay is from that of marl. No known agent can ever force them from the circle of combinations peculiar to their nature. Places which produce marble and stone will always continue to do so, as infallibly as those that produce only sandstone, flint, and granite, will never produce lime-stones or marble.

If we examine the order and distribution of the materials of a hill composed of vitrifiable substances, we shall generally find, under the vegetable soil, a stratum of clay, which is likewise a vitrifiable substance, analogous to flint, and which, as already remarked, is only a decomposition of vitrifiable sand; or, rather, we shall find, under the soil, a stratum of vitrifiable sand. This stratum of clay or of sand corresponds with the bed of gravel in hills consisting of calcinable matters. Below the stratum of clay or of sand, we meet with some beds of free-stone, which seldom exceed half a foot in thickness, and they are divided into small portions by perpendicular fissures. Under these are several strata of the same matter, and likewise beds of vitrifiable sand. In proportion as we descend, the free-stone is more dense, and its thickness increases. Below these, we find what I call live rock, or flint in large masses, a substance so hard as to resist the file, and all kinds of acids, more powerfully than vitrifiable sand or powder of glass, upon which aquafortis seems to have some effect. When struck with another hard body, it throws out sparks of fire, and exhales a penetrating sulphureous vapour. This flinty substance is commonly found along with beds of clay, of slate, of pit-coal, of vitrifiable sand; and it corresponds to the strata of hard stone and marble, which serve as the bases of hills that consist of calcinable matter.

The waters, in passing through the perpendicular fissures, and in penetrating the strata of

vitrifiable sand, of free-stone, of clay, and of slate, are impregnated with the finest and most homogeneous particles of these substances, and produce various concretions, such as talc, asbestos, and other bodies, which owe their existence to distillation through vitrifiable matter.

Flint, notwithstanding its hardness and density, has, like marble and common stone, its exudations, from which result stalactites of different species, varying in transparency, colour, and configuration, according to the nature of the flint that produces them, and to the different metallic or heterogeneous particles it contains. Rock crystal, all the precious stones, and even the diamond itself, may be regarded as stalactites of this kind. The flints in small masses, the strata or coats of which are generally concentric, are only stalactites or parasitical stones from the flints in large masses; and most of the fine opaque stones are nothing but species of flint. The substances produced by the vitrifiable class of bodies are not, as we have seen, so various as the concretions formed by those of the calcinable. Most of the concretions formed by flint are hard and precious stones; but those produced by calcarious stones are friable, and of no value.

Perpendicular fissures are found in flint rocks as well as in stone. They are even frequently larger in flint, which proves this substance to be drier than stone. Both the hill consisting of calcinable, and that composed of vitrifiable matter, have clay or vitrifiable sand for their bases, which

are the most commonly diffused matters of the globe, and which I regard as the lightest, being the scoriæ of the vitrified matter that constitutes the interior parts of the earth. Thus all mountains, as well as plains, are founded either on clay or sand. We have seen, for example, in the pits of Amsterdam, and in that of Marly-la-Ville, that vitrifiable sand was always the deepest stratum.

It may be observed, in most bare rocks, that the walls of perpendicular fissures, whether they be narrow or wide, correspond as exactly with each other as split pieces of wood. In the large quarries of Arabia, which consist mostly of granite, the perpendicular fissures are frequent; and though some of them are twenty or thirty yards wide, the sides correspond exactly, and leave a deep cavity between them*. It is likewise common to find, in perpendicular fissures, shells divided into two pieces, each piece remaining attached to the opposite sides of the fissure; which proves that these shells were deposited in the solid stratum before it was split†.

In some quarries mentioned by Mr. Shaw, the perpendicular fissures are exceedingly large; and for this reason, perhaps, they are less numerous. In quarries of granite and flint in large masses, blocks of stone may be raised, as the obelisks and columns at Rome, of 60, 80, 100, and 150 feet long, without the least interruption. It appears, that these vast blocks have been raised from the

* See Shaw's Travels. † See Woodward, p. 298.

same quarry, and, like some species of free-stone, that they may be had of any given thickness. In other substances, the perpendicular fissures are very narrow, as in clay, in marl, and in chalk; and they are wider in marble and hard stone. Some are imperceptible, because they have been filled with a matter nearly similar to that of the stone itself; but still they interrupt the continuity of the stones, and are called *hairs* by the workmen. I have often remarked, that these hairs in marble and stone differed from perpendicular fissures only in the separation of parts not being complete. These species of fissures are filled with a transparent matter, which is a true spar. In quarries of free-stone, the fissures are numerous, and considerably large, because rocks of this kind have often a less solid base than that which supports marble or lime-stone, the former generally resting upon a fine sand, and the latter upon clay. In many places, free-stone is not to be found in large masses; and in most quarries, where this stone is good, the blocks lie irregularly upon one another, in the form of cubes or parallelopipeds, as in the hills of Fountainbleau, which appear, at a distance, like the ruins of old buildings. This irregular disposition has been occasioned by the sandy foundation of these hills allowing the blocks to sink and tumble upon each other, especially where quarries have been formerly wrought, which has given rise to a great variety of fissures and intervals between the different blocks: and it may be remarked, in all countries abounding

with sand and free-stone, that there are many fragments of rocks and large stones in the middle of the plains and valleys; and that, on the contrary, in countries abounding with marble and hard stone, these scattered fragments, which have rolled down from the hills, are exceedingly rare. This phænomenon is owing to the different solidities of the bases upon which these stones are supported, and to the extent of the banks of marble or lime-stone, which is always more considerable than that of free-stone.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVIII.

Of the Effects of Rains — Of Marshes, Subterraneous Wood and Waters.

IT has already been remarked, that rains, and the currents of water which they produce, continually detach, from the summits and sides of mountains, earth, gravel, &c., and carry them down to the plains; and that the rivers transport part of them to the sea. The plains, therefore, by fresh accumulations of matter, are perpetually rising higher; and the mountains, for the same reason, are constantly diminishing both in size and elevation. Of the sinking of mountains, Joseph Blancanus relates several facts which were publicly known in his time. The steeple of the village of Craich, in the county of Derby, was not visible in 1572, from a certain

mountain, on account of a higher mountain which intervened; but eighty or one hundred years afterwards, not only the steeple, but likewise part of the church, were visible from the same station. Dr. Plot gives a similar example of a mountain between Sibbertoft and Ashby, in the county of Northampton. Sand, earth, gravel, and small stones, are not only carried down by the rains, but they sometimes undermine and drive before them large rocks, which considerably diminish the height of mountains. In general, the rocks are pointed and perpendicular in proportion to the height and steepness of mountains. The rocks in high mountains are very straight and naked. The large fragments which appear in the valleys have been detached by the operation of water and of frosts. Thus sand and earth are not the only substances detached from mountains by the rains; they attack the hardest rocks, and carry down large fragments of them into the plains. At Nant-phrancon, in 1685, a part of a large rock, which was supported on a narrow base, being undermined by the waters, fell, and split into a number of fragments, the largest of which made deep trenches in the plain, crossed a small river, and stopped on the other side. To similar accidents we must ascribe the origin of all those large stones which are found in valleys adjacent to mountains. This phænomenon, as formerly remarked, is more common in countries where the mountains are composed of sand and free-stone, than

in those the mountains of which consist of clay and marble; because sand is a less solid basis than clay.

To give an idea of the quantity of earth detached from mountains by the rains, we shall quote a passage on this subject from Dr. Plot's Natural History of Stafford. He remarks, that a great number of coins, struck in the reign of Edward IV. *i. e.* 200 years ago, were found buried eighteen feet below the surface: hence, he concludes, that the earth, which is marshy where the coins were found, augments about a foot in eleven years, or an inch and a twelfth each year. A similar observation may be made on trees buried seventeen feet below the surface, under which were found medals of Julius Cæsar. Thus, the soil of the plains is considerably augmented and elevated by the matters washed down from the mountains.

The rupture of caverns, and the action of subterraneous fires, are the chief causes of the great revolutions which happen in the earth; but they are often produced by smaller causes. The filtration of the water, by diluting the clay, upon which almost all calcarious mountains rest, has frequently made those mountains incline and tumble down. Of these remarkable events I shall subjoin some examples.

"In the year 1757," says M. Perronet, "a part of the ground situated about half way before we arrive at the Castle of Croix-fontaine, opened in many places, and successively tumbled down.

The terrace wall, which inclosed this ground, was overturned, and the road, which was formerly at the foot of the wall, was obliged to be carried to a considerable distance. . . . . . This ground rested upon a base of inclined earth." This learned and chief engineer of our highways and bridges mentions another accident of the same kind, which happened, in the year 1733, at Pardines, near Issoire, in Auvergne. The ground, for about 400 fathoms in length by 300 in breadth, descended upon a pretty distant meadow, with all its houses, trees, and herbage. He adds, that considerable portions of ground are sometimes transported either by the rupture of reservoirs of water, or by the sudden melting of snows. In 1757, at the village of Guet, about ten leagues from Grenoble, on the road to Briançon, the whole ground, which lies on a declivity, slipped, and descended in an instant towards Drac, which is about a mile distant. The earth split in the village, and the part which moved off was six, eight, and nine feet lower than its former station. This ground was situated on a pretty solid rock, which was inclined to the horizon about forty degrees *.

To these examples I shall add another fact, of which I have been a constant witness, and which has cost me a considerable expense. The detached rising ground, upon which the town and old castle of Montbard are situated, is elevated 140 feet above the level of the river, and its most

* Hist. de l'Acad. des Sciences, ann. 1769, p. 233.

rapid descent is to the north-east. This rising ground is crowned with calcarious rocks, the strata of which, when taken together, are fifty-four feet thick. They every where rest upon a mass of clay, which, of course, before reaching the level of the river, is eighty-six feet thick. My garden, which is surrounded with several terraces, is situated on the top of this rising ground. From twenty-five to twenty-six fathoms of the last terrace wall on the north-east side, where the declivity is greatest, gave way all at once, carrying along the inferior ground, which would have gradually descended to the level of the ground near the river, if its progressive motion had not been prevented by taking down the whole wall. This wall was seven feet thick, and founded on clay. The movement of the earth was very slow: I perceived that it was evidently occasioned by the insinuation of water. All the water which falls upon the platform on the top of this rising ground, penetrates through the fissures of the rocks, and reaches the clay upon which they rest: of this fact we are ascertained by two wells dug from the top of the rock to the clay. All the rain-water, therefore, which falls upon this platform and the adjacent terraces, collects upon the clay where the perpendicular fissures of the rock terminate. The water gives rise to small rills in different places, which are rendered still more apparent by several wells dug below the rocks. Wherever this mass of clay is cut by ditches, we see the water filtrating from above. It is not, therefore, surprising, that walls, however solid,

should slip upon this first bed of moist clay, if they are not founded much lower, as I have done in rebuilding them. The same thing, however, has happened on the north-west side, where the declivity is gentler, and no rills of water appear. The clay had been removed at the distance of twelve or fifteen feet from a great wall, of eleven feet thick, thirty-five feet high, and twelve fathoms long. This wall is constructed of good materials, and has subsisted more than 900 years. The cut from which the clay was removed, though not above four or five feet deep, has produced a movement in this immense wall. It declines from the perpendicular about fifteen inches, and I could only prevent its downfal by abutments of seven or eight feet thick, and founded at the depth of fourteen feet.

From these facts I drew the following conclusion, which is not so interesting at present as it would have been in ages that are past, that there is not a castle or fortress, situated upon heights, which might not be easily tumbled into the plain by a simple cut of ten or twelve feet deep and some fathoms wide. This cut should be made at a small distance from the last wall, and upon that side where the declivity is greatest. This method, of which the ancients never dreamed, would have saved them the operation of battering rams and other engines of war; and, even at present, might be employed, in many cases, with advantage. I am convinced by my eyes, that, when these walls slipt, if the cut made for rebuilding them had not been

speedily filled with strong mason work, the ancient walls, and the two towers that have subsisted in good condition 900 years, and one of which is 125 feet high, would have tumbled into the valley, along with the rocks upon which they are founded. As most of our hills composed of calcarious stones rest upon a clay base, the first strata of which are always more or less moistened with the waters that filtrate through the crevices of the rocks, it appears to be certain, that, by exposing these moistened beds to the air by a cut, the whole mass of rocks and earth resting upon the clay would slip, and in a few days tumble into the cut, especially during wet weather. This mode of dismantling a fortress is more simple than any hitherto invented; and experience has convinced me that its success is certain.

The sand, gravel, and earth, carried down from the mountains into the plains, form beds which ought not to be confounded with the original strata of the globe. To the former belong the beds of tufa, of soft stone, and of sand and gravel which have been rounded by the operation of water. To these may be added those beds of stone which have been formed by a species of incrustation, none of which derive their origin from the motion or sediments of the sea. In these strata of tufa and of soft imperfect stones, we find a number of different vegetables, leaves of trees, land or river shells, and small terrestrial animals, but never sea shells, or other productions of the ocean. This circumstance, joined

to their want of solidity, evidently proves, that these strata have been superinduced upon the dry surface of the earth, and that they are more recent than those of marble and other stones, which contain sea shells, and have been originally formed by the waters of the sea. Tufa, and other new stones, appear to be hard and solid when first dug out of the earth; but they soon dissolve after being exposed to the operation of the weather. Their substance is so different from that of true stone, that, when broken down in order to make sand of them, they change into a kind of dirty earth. The stalactites, and other stony concretions, which M. Tournefort apprehended to be marbles that had vegetated, are not genuine stones. We have already shown, that the formation of tufa is not ancient: and that it is not entitled to be ranked with stones. Tufa is an imperfect substance, differing from stone or earth, but deriving its origin from both by the intervention of rain-water, in the same manner as incrustations are formed by the waters of certain springs. Thus, the strata of these substances are not ancient; nor have they, like the other species, been formed by sediments from the waters of the ocean. The strata of turf are also recent, and have been produced by successive accumulations of half corrupted trees and other vegetables, which owe their preservation to a bituminous earth. No production of the sea ever appears in any of these new strata. But, on the contrary, we find in them many vegetables, the bones of land animals, and land and river shells. In the

meadows near Ashly, in the county of Northampton, for example, they find, several feet below the surface, snail shells, plants, herbs, and several species of river shells, well preserved; but not a single sea shell appears *. All these new strata have been formed by the waters on the surface changing their channels, and diffusing themselves on all sides. Part of these waters penetrate the earth, and run along the fissures of rocks and stones. The reason why water is so seldom found in high countries, or on the tops of hills, is, because high grounds are generally composed of stones and rocks. To find water, therefore, we must cut through the rocks till we arrive at clay or firm earth. But, when the thickness of the rock is great, as in high mountains, where the rocks are often 1,000 feet high, it is impossible to pierce them to their base; and consequently it is impossible to find water in such situations. There are even extensive countries that afford no water, as in Arabia Petrea, which is a desert where no rains fall, where the surface of the earth is covered with burning sands, where there is hardly the appearance of any soil, and where nothing but a few sickly plants are produced. In this miserable country, wells are so rare, that travellers enumerate only five between Cairo and Mount Sinai, and the water they contain is bitter and saltish.

When the superficial waters can find no outlets or channels, they form marshes and fens.

* See Phil. Trans. abridg. vol. iv. p. 271.

The most celebrated fens in Europe are those of Russia, at the source of the Tanais; and those of Savolaxia and Enasak, in Finland: there are also considerable marshes in Holland, Westphalia, and other countries. In Asia are the marshes of the Euphrates, of Tartary, and of the Palus Meotis. However, marshes are less frequent in Asia and Africa than in Europe. But the whole plains of America may be regarded as one continued marsh; which is a greater proof of the modernness of this country, and of the scarcity of its inhabitants, than of their want of industry.

There are extensive fens in England, particularly in Lincolnshire, near the sea, which has lost a great quantity of land on one side, and gained as much on the other. In the ancient soil, many trees are found buried under the new earth, which has been transported and deposited by the water: the same phænomenon is common in the marshes of Scotland. Near Bruges in Flanders, in digging to the depth of forty or fifty feet, a vast number of trees were found, as close to each other as they are in a forest. Their trunks, branches, and leaves, were so well preserved, that their different species could be easily distinguished. About 500 years ago, the earth where these trees were found was covered with the sea: and, before this time, we have neither record nor tradition of its existence. It must, however, have been dry land when the trees grew upon it. Thus the land, that, in some remote period, was firm, and covered with wood,

has been overwhelmed with the waters of the sea, which, in the course of time, have deposited forty or fifty feet of earth upon the ancient surface, and then retired. A number of subterraneous trees was likewise discovered at Youle in Yorkshire, near the river Humber. Some of them are so large as to be of use in building; and it is affirmed that they are as durable as oak. The country people cut them into long thin slices, and sell them in the neighbouring villages, where the inhabitants employ them for lighting their pipes. All these trees appear to be broken; and the trunks are separated from the roots, as if they had been thrown down by a hurricane or an inundation. The wood appears to be fir, it has the same smell when burnt, and makes the same kind of charcoal *. In the Isle of Man, there is a marsh called Curragh, about six miles long and three broad, where subterraneous fir trees are found; and, though eighteen or twenty feet below the surface, they stand firm on their roots †. These trees are common in the marshes and bogs of Somerset, Chester, Lancashire, and Stafford. In some places, there are subterraneous trees, which have been cut, sawed, and squared by the hands of men; and even axes, and other implements, are often found near them. Between Birmingham and Bromley, in the county of Lincoln, there are hills of a fine light sand,

* See Phil. Trans. num. 228.

† See Ray's Discourses, p. 232.

which is blown about by the winds, and transported by the rains, leaving bare the roots of large firs, in which the impressions of the axe are still exceedingly apparent. These hills have unquestionably been formed, like downs, by successive accumulations of sand transported by the motions of the sea. Subterraneous trees are also frequent in the marshes of Holland, Friesland, and near Groningen, which abound in turfs.

In the jurisdiction of Bergues-Saint-Winock, Furnes, and Bourbourgh, we find turf at three or four feet below the surface. These beds of turf are generally two feet thick, and are composed of corrupted wood, of entire trees, with their branches and leaves, and particularly of filberds, which are known by their nuts, and the whole is interlaced with reeds and the roots of plants.

What is the origin of these beds of turf, which extend from Bruges through the whole flat country of Flanders as far as the river Aa, between the downs and the high country in the environs of Bergues, &c.? In remote ages, when Flanders was only a vast forest, a sudden inundation of the sea must have deluged the whole country, and, in retiring, deposited all the trees, wood, and twigs, which it had eradicated and destroyed in this lowest territory of Flanders; and this event must have happened in the month of August or September; because we still find the leaves of trees, as well as nuts, on the filberds. This inundation must have taken place long before that province was conquered by Julius Cæsar, since

nŏ mention is made of it in the writings of the ancients *.

In the bowels of the earth we sometimes find vegetables in a different state from that of common turf. For example, in Mount Ganelon, near Compeigne, we find, on one side of the mountain, quarries of fine stones and the fossil oysters formerly mentioned, and, on the other side, we meet with a bed of the leaves of all kinds of trees, and also reeds, the whole blended together and inclosed in mud. When these leaves are stirred, we perceive the same musty odour which we feel on the margin of the sea; and these leaves preserve their odour during several years. Besides, the leaves are not destroyed; for we can easily distinguish their species: they are only dry, and slightly united to each other by the mud †.

"We distinguish," M. Guettard remarks, "two species of turf: the one is composed of marine, and the other of terrestrial plants. We suppose the first to have been formed when the sea covered all those parts of the earth which are now inhabited. The second is supposed to have been superinduced upon the former. According to this system, it is imagined that the currents carried the sea plants into the hollows formed by the mountains, which were elevated above the

* Mem. pour la Subdelegation de Dunkerque, relativement à l'Hist. Nat. de ce Canton.

† Lettre de M. Leschevin à M. de Buffon; Compeigne, 8 Aout, 1772.

waters, and, after being tossed about by the waves, were deposited in the hollows.

"This origin of turf is not impossible: the great quantity of sea plants is sufficient to account for the phænomenon. The Dutch even allege, that the goodness of their turf is owing to the bitumen with which the sea water is impregnated, and that they were formed by sea weeds.

"The turf pits of Villeroy are situated in the valley through which the river Essone runs; and part of this valley extends from Roissy to Escharcon. . . . . . It is even near Roissy that turfs were first dug. . . . . . But those near Escharcon are the best. . . . . .

"The meadows where turf is dug are open and bad: they are filled with rushes, horse-tail, and other plants, which grow in bad soils. These meadows are dug to the depth of eight or ten feet. . . . . . Next to the upper stratum, there is a bed of turf about a foot thick, and impregnated with river and land shells. . . . . .

"This bed of turf, filled with shells, is commonly earthy: those which succeed are nearly of the same thickness, and are always better as we descend. These turfs are of a blackish brown colour, intermixed with reeds, rushes, and other plants. We see no shells in these beds. . . . . .

"In masses of turf we sometimes find the stems of willows and poplars, and sometimes the roots of these and similar trees. On the Escharcon side, an oak was discovered at the depth of nine feet. It was black, and almost corrupted.

It crumbled into dust, after being exposed to the air. Another was found, on the Roissy side, between the soil and the turf, at the depth of two feet. Near Escharoon, the horns of a stag were found three or four feet below the surface. . . . .

"Turfs are perhaps equally abundant in the environs of Etampes, as near Villeroy. These turfs contain but very little moss. Their colour is a fine black. They are heavy, and burn well in an ordinary fire. Good charcoal might be made of them. . . . . .

"The turfs in the neighbourhood of Etampes may be considered as a continuation of those of Villeroy. In a word, all the meadows adjacent to the river of Etampes are probably full of turf. The same remark is applicable to the meadows through which the river Essone runs: these meadows produce the same plants as those of Etampes and Villeroy *."

According to this author, there are in France a number of places from which turf may be obtained, as at Bourneuille, at Croué, near Beauvais, at Bruneval, in the environs of Péronne, in the diocese of Troyes in Champagne, &c. This combustible substance would be a great resource, if it were used in such places as want wood.

There are likewise turfs near Vitri-le-François, and in the morass along the Marne. These turfs are good, and contain great quantities of acorn shells. The marsh of Saint-Gon, in the environs of Châlons, is full of turf, which the

* Mem. de l'Acad. des Sciences, ann. 1761, p. 380—397.

inhabitants will soon be obliged to use for want of wood *.

Subterraneous trees are of different species, *viz.* firs, oaks, birch, beech, yew, hawthorn, willow, ash, &c. In the fens of Lincoln, along the river Ouse, and on Hatfield-chace in Yorkshire, these trees stand erect, as if they were growing in a forest. The oaks are extremely hard, and are used in building, where they are said to last long, which I think improbable, as all the specimens I have examined lose their solidity, after being dried and exposed to the air. The ashes are tender, and soon fall into dust. Some of these trees are evidently cut and sawed with instruments; and the hatchets, which are sometimes found along with them, resemble the knives formerly used in sacrifices. Beside trees, we also meet with vast quantities of filberds, acorns, and fir-cones, in many other fens, in England, Scotland, and Ireland, as well as in the marshes of France, Switzerland, Savoy, and Italy †.

For four miles round the town of Modena, whenever the earth is dug to the depth of sixty-three feet, the workmen pierce about five feet more with a boring instrument, through which the water rushes up with such impetuosity, that it fills the wells to the top, almost instanta-

* Note communicated to M. de Buffon, by M. Greignon, Aug. 6, 1777.

† See Phil. Trans. abridg. vol. iv. p. 218, &c.

neously. The water in these wells continues perpetually, and is neither augmented nor diminished by rains or drought. What is still more remarkable in this spot, whenever the workmen dig to the depth of fourteen feet, they find the rubbish and ruins of an ancient city, paved streets, houses, and different pieces of Mosaic work. Below this, the earth is solid, and appears not to have been moved. Still lower, however, we find a moist soil, mixed with vegetables; and, at the depth of twenty-six feet, entire trees, as filberds, with nuts upon them, and great quantities of branches and leaves. At twenty-eight feet, there is a stratum of soft chalk, eleven feet thick, mixed with sea shells; and after this we still meet with vegetables, leaves and branches of trees, till we arrive at the depth of sixty-three feet, where there is a stratum of sand mixed with gravel and shells, similar to those which appear on the coasts of Italy. These successive strata lie always in the same order, wherever pits have been dug; and sometimes the boring instrument falls in with the trunks of large trees. which the workmen pierce with great labour: they likewise meet with bones of animals, pit-coal, flints, and pieces of iron. Ramazzini, who relates these facts, thinks, that the gulf of Venice formerly extended beyond Modena, and that this land, in the progress of time, has been gradually formed by the rivers, assisted, perhaps, by inundations of the sea.

" In the territories of the duke of Saxe-Co-

burg, which lie on the frontiers of Franconia and Saxe, and at some leagues from the town of Coburg, were found, at a small depth, whole trees, so completely petrified, that they were as beautiful and hard as agates. Some specimens of them were given by the princes of Saxe to M. Schoepflin, who transmitted two of them to M. de Buffon for the Royal Cabinet. Vases and other beautiful utensils have been made of this petrified wood *."

Wood in its natural state has likewise been found at great depths. M. du Verny, an officer of artillery, sent me some specimens of it accompanied with the following letter: "The town of Fère, in the garrison of which I am stationed, on the 15th of August, 1753, ordered a search to be made for water by means of boring: at thirty-nine feet below the surface, they found a bed of marl, which they continued to pierce for 121 feet: hence, at the depth of 160 feet, they found, at two different trials, the augre filled with marl, intermixed with numerous fragments of wood, which every person easily recognised to be oak. I send you two specimens of this wood. During the succeeding days' operations, they continued to find the same marl, but not so much mixed with wood, as far as the depth of 210 feet, where they ceased to bore †."

"In the territory of Coburg, which is a

* Lettre de M. Schoepflin, Strasbourg, Sept. 24, 1746.

† Lettre de M. Bresse du Verny; La Fère, Nov. 14, 1753.

branch of the house of Saxe, we find," M. Justi remarks, "petrified wood of a prodigious size. In the mountains of Misnia, entire trees have been dug out of the earth, which were converted into very fine agate. The imperial cabinet of Vienna contains many petrifications of this kind. A great log of this wood was sent to the same cabinet: the part which had been wood was changed into a beautiful agate of a grayish black colour; and, instead of bark, the trunk was surrounded with a belt of fine white agate. . . . . .

"The present emperor wished that a method of ascertaining the age of petrifactions might be discovered. . . . . . He ordered his ambassador at Constantinople to ask permission to take up from the Danube one of the piles of Trajan's bridge, which is some miles below Belgrade. This permission being granted, one of the piles was drawn up, which it was imagined would have been petrified by the water. But, after such a lapse of time, it was discovered that the process of petrifaction had made very little progress. Though this pile had remained in the Danube above 1,600 years, the petrifaction had not proceeded above three quarters of an inch, and even less. The rest of the wood was very little altered, and had only begun to be calcined.

"If a just conclusion, with regard to all other petrifactions, could be drawn from this single fact, nature would perhaps require 50,000 years

to change trees, of the size of those found petrified in certain places, into stones. But, in particular situations, many causes may concur in hastening the process of petrifaction. . . . . .

"At Vienna there is to be seen a petrified log, which was brought from the Carpathian mountains in Hungary. Upon this log the marks of the hatchet, which had been made before its petrifaction, are distinctly visible; and these marks are so little altered by the change the wood has undergone, that we perceive they have been made by a small instrument. . . . . .

"Besides, it appears that petrified wood is not so rare as is commonly imagined; and that, to discover it in many places, requires only the nice eye of a naturalist. Near Mansfield, I saw a great quantity of petrified oak in a place where many people daily pass, without perceiving this phænomenon. Some logs were entirely petrified, and in these we distinctly perceived the rings formed by the annual growth, the bark, the place where they were cut, and all the characters of oak wood *."

M. Clozier, who found different pieces of petrified wood upon the hills in the neighbourhood of Etampes, and particularly on that of Saint Symphorien, imagined that these fragments might have proceeded from some petrified trunks in the mountains. He therefore

* Journal Etranger, mois d'Octobre, 1756, p. 160.

caused pits to be dug in a part of the mountain of Saint Symphorien that had been pointed out to him. After digging several feet deep, he first discovered a petrified root, which led him to the trunk of a tree of the same species.

"This root, from its extremity to its junction with the trunk, was," says M. Clozier, "five feet in length; there were other five roots, but not equally long. . . . . .

"The middling and small roots were not petrified, or at least their petrification was so brittle, that they remained in the sand, where the trunk was in the form of powder or ashes. It is reasonable to think, that, when the process of petrifaction was communicated to these roots, they had been almost corrupted, and that the ligneous parts of which they were composed, being too much separated by petrifaction, could not acquire the degree of solidity necessary to a genuine petrifaction. . . . . .

"The thickest part of the trunk was near six feet in circumference. Its length was three feet ten inches, and its weight was from 500 to 600 pounds. The trunk, as well as the roots, had all the appearance of wood, as the bark, the inner rind, the solid and corrupted wood, the holes of large and small worms, and even the excrements of these worms. All these parts were petrified, but were not so solid and hard as the ligneous body, which had been perfectly sound when the process of petrifaction commenced. The ligneous body is converted into

a real flint of various colours, which strikes fire with steel, and produces, after being struck or rubbed, a very strong smell of sulphur. . . . . .

"This petrified trunk was bedded in a horizontal direction. . . . . It was covered with more than four feet of earth, and its root was not above two feet below the surface *."

M. l'Abbé Mazéas, who discovered, at half a mile from Rome, a quarry of petrified wood, expresses himself in the following terms:

"This quarry of petrified wood forms a succession of hillocks in the front of Monte-Mario, on the other side of the Tiber. . . . . Of these fragments of wood, irregularly heaped upon each other, some have the appearance of a hard dry earth, which seems not to be fit for the nourishment of vegetables: others are petrified, and have the colour, the brilliancy, and the hardness of the resin, known in the shops by the appellation of *colophanus*. This petrified wood is found in a soil similar to the former, but more moist. Both are perfectly well preserved. The whole are reduced, by calcination, into a true earth; and none of them produce alum, either by the application of fire, or by combining them with the vitriolic acid †."

M. du Monchau, a physician and expert naturalist, has sent me, for the Royal Cabinet, a piece of petrified wood with the following historical account:

* Mem. des Savans Etrangers, tom ii. p. 598—604.

† Ibid. tom v. p. 388.

"The piece of petrified wood, which I have the honour of transmitting to you, was found at the depth of more than 150 feet below the surface. . . . . Last year (1754), when digging a pit in quest of coal, at Notre-Dame-au-bois, a village situated between Condé, Saint Amand, Mortagne, and Valenciennes, we found, about 600 fathoms from Escaut, and after passing three water levels, first seven feet of rock or hard stone, called *tourtia* in the language of colliers; afterwards, when we arrived at a marshy earth, we found, at the depth of 150 feet, as already remarked, the trunk of a tree of two feet in diameter, which lay across the pit, and, of course, we were prevented from measuring its length. It rested upon a large free-stone; and many pieces were cut off from this trunk by the curious. The small fragment I have the honour of sending you was cut off from a specimen given to M. Laurent, a learned mechanic. . . . .

"This wood seemed rather to have been converted into coal than petrified. How could a tree be sunk so deep into the earth? Has the soil in which the tree was found been formerly as low? If that is the case, how could this soil be augmented 150 feet? From whence did all this earth proceed?

"The seven feet of *tourtia* observed by M. Laurent, which exists also in all the coal mines for ten leagues round, have, according to the above supposition, been produced posterior to this accumulation of earth.

"I leave this matter, sir, to your decision:

you are so intimately acquainted with Nature, that none of her mysteries can be long concealed from you; and I have no doubt that you will be able to explain this wonderful phænomenon *."

M. Fougeroux de Bondaroy, of the Royal Academy of Sciences, relates several facts concerning petrified wood, which merit attention.

"All the fibrous stones," he remarks, "which have some resemblance to wood, are not petrified wood. But there are many others which must be recognised as such, especially if we attend to the peculiar organization of vegetables. . . . .

"Facts are not wanting to prove that wood may be converted into stone, with as much ease at least as several other substances which incontestibly undergo this transmutation. But it is difficult to explain how this effect is produced. I hope I may be permitted to hazard some conjectures on the subject, which I shall endeavour to support by facts and observations.

"We find wood which may be considered as only half petrified, and not much heavier than common wood. Specimens of this kind are easily divided into plates, or even into filaments, like certain corrupted timber. Others are more petrified, and have the weight, the hardness, and the opacity of free-stone. Others, whose petrifaction is still more perfect, admit the same po-

* Lettre de M. Dumonchau à M. de Buffon; Douai, Jan. 29, 1755.

lish as marble; while others acquire that of fine oriental agates. I have an excellent specimen sent from Martinico to M. du Hamel, which is converted into a most beautiful sardonix. Lastly, we find wood changed into slate. Among these specimens, there are some which have retained the organization of wood so completely, that we discover with a lens every appearance exhibited in unpetrified wood.

"We have seen some specimens encrusted with a sandy iron ore, and others penetrated with a substance, which, being composed of sulphur and vitriol, makes them approach the state of pyrites. Some of them are, if we may use the expression, larded with a very pure iron ore; and others are traversed by veins of very black agate.

"We find pieces of wood, one part of which is converted into a stone, and the other into agate: the part converted into stone is tender; but the other has the hardness peculiar to precious stones.

"But, how should certain pieces, though converted into hard agate, preserve the distinct characters of organization, as the concentric circles, the insertions, the extremities of the tubes destined to transmit the sap, the bark, the inner rind, and the wood? If the vegetable substance were entirely destroyed, we should only see an agate, without any of the organic characters formerly mentioned. To preserve this appearance of organization, if we suppose that the wood subsists, and that the pores alone are

filled with the petrifying juice, it should appear, that the vegetable parts might be extracted from the agate. But I could never make any progress in this operation: I therefore think, that the specimens in question retain no parts which have preserved the nature of wood. To give perspicuity to my idea, I beg the reader to recollect, that, when a piece of wood is distilled in a retort, the coal which remains after distillation is not a sixth part of the original weight of the wood. When this coal is burnt, we obtain only a small quantity of ashes, which will still diminish after the lixivial salts are abstracted.

"This small quantity of ashes being the only fixed part, the chemical analysis proves, that the fixed parts of a piece of wood are really very trifling, and that the greatest portion of vegetable matter is destructible, and may be gradually carried off, as the wood corrupts.

"Now, if we consider that the greater part of the wood is destroyed, and that what remains is a light earth, and easily permeable by the petrifying juice, its conversion into stone, agate, or sardonix, will not be more difficult to conceive than that of bole, clay, or any other earth. The only difference is, that the vegetable earth preserves the appearance of organization, and the petrifying juice insinuates into its pores, without destroying its original characters *."

Some facts and observations remain still to be added. In August, 1773, at Montigni-sur-

* Mem. de l'Acad. des Sciences, ann. 1759, p. 431—452.

Braine, in the district of Challon and jurisdiction of Auxonne, when digging a copper mine, the workmen, at the depth of thirty-three feet, found a tree lying on its side; but the species of it could not be discovered. The superior strata seemed to have never been touched by the hand of man; for, below the soil, there was a bed of eight feet of clay; then ten feet of sand; then a bed of fullers earth about six or seven feet; then another bed of the same mixed with stones; and, lastly, a bed of black sand of three feet. The tree was found in the fullers earth. The river Braine is to the east, and not above a gun-shot from this place. It runs in a meadow eighty feet lower than the site of the copper *.

M. de Greignon informed me, that, on the borders of the Marne, near St. Dizier, there is a bed of pyritous wood, the organization of which is apparent. This bed is situated under a stratum of free-stone, which is covered with a stratum of pyrites, and above the pyrites is a stratum of lime-stone. The bed of pyritous wood lies upon a blackish clay.

He likewise found, in the pits dug for discovering the subterraneous town of Châtelet, instruments of iron with wooden handles. He remarked that this wood was converted into a genuine iron ore, of the hematites species. The organization of the wood was not destroyed; but it was brittle, and its whole texture was as

* Lettre de Mad. la Comtesse de Clermont-Montoison à M. de Buffon.

close as that of the hematites. These iron instruments with wooden handles had been buried in the earth sixteen or seventeen hundred years. The conversion of the wood into hematites had been affected by the decomposition of the iron, which had gradually filled all the pores of the wood.

" In the parish of Haux, which is situated between two seas, and about half a league from the port of Langoiran, a point of a rock, of eleven feet high, detached itself from the coast, which was formerly thirty feet high. By its fall it spread over the valley a great quantity of animal bones, or fragments of bones, some of which were petrified. That they are bones is unquestionable; but it is difficult to ascertain the animals to which they belong. The greatest number consists of teeth; some of them perhaps belong to the ox or horse; but, without marking the difference in figure, most of them are larger than the teeth of these animals. There are likewise thigh or leg bones, and a fragment of a stag or elk's horn. The whole are covered with common earth, and situated between two strata of rock. We must suppose that the carcasses of animals have been thrown into a hollow rock, and, after the flesh had corrupted, a rock of eleven feet high had been formed above them, which would require the operation of many ages. . . . .

" The gentlemen of the Academy of Bourdeaux, who examined these bones with philosophical accuracy, discovered, that when a number

of fragments were put on a very brisk fire, they were converted into a fine Turquois blue; and that some portions became so hard, that, when cut by a lapidary, they received a fine polish. . . . . . It must also be remarked, that bones which evidently belonged to different animals were equally converted into Turquois*."

"On the 28th of January, 1760," says M. de Guettard, "there were found, 160 fathoms above the mineral baths, bones included in a rock with a gray surface. This rock was neither laminated nor consisted of separate strata, but was one continued mass of stone. . . . . .

"After having, by means of gunpowder, penetrated five feet deep into this rock, we found a great number of human bones belonging to every part of the body, as jaw-bones with their teeth, bones of the arms, thighs, limbs, ribs, rotulæ, &c., jumbled together in the greatest disorder. Entire skulls, or portions of them, chiefly prevailed.

"Besides these human bones, we met with several fragments which could not be ascribed to man. In some places, they are in continued masses, and in others more dispersed. . . . . .

"When we arrived at the depth of four feet and a half, we found six human heads in an inclined position. In five of these heads, the occiput with its appendages, except the bones of the face, were preserved. This occiput was partly encrusted with stone, its cavity was filled

* Hist. de l'Acad. des Sciences, ann. 1719, p. 24.

with stone, and had assumed the same mould or figure. In the sixth head, the face is entire: it is broad in proportion to its length. We easily distinguish the form of the fleshy cheeks. The eyes are shut, pretty long, but narrow. The front is large, and the nose very flat, but well formed; the middle line is distinguishable. The mouth is well made, and shut; the upper lip is a little thick in proportion to the under. The chin is well proportioned, and the whole muscles are strongly marked. The colour of the head is reddish, and resembles those of the Tritons feigned by painters. Its subtance is similar to that of the stone in which it was found; it is, properly speaking, only the mask of the natural head."

The above relation was sent by M. le Baron de Gaillard-Lonjumeau to Madame de Boisjourdain, who transmitted it to M. Guettard, with some specimens of the bones. That these bones were really human, is a very doubtful point; "for every appearance in this quarry," M. de Lonjumeau remarks, "announces that it has been formed of relics of bodies broken in pieces, and which had been long tossed about by the waves of the sea before they were collected into one heap. As this mass of bones lies horizontally, and has been successively covered with stony matter, it is easy to conceive how a mask was formed on the faces of those heads, the flesh having little time to corrupt, especially when the bodies were buried under

the water. We may, therefore, reasonably conclude, that these heads were not human. . . . . They rather seem to be the heads of those fishes, whose teeth are found in the same parts of the stones along with the bones supposed to belong to the human species.

"It appears that the collection of bones in the environs of Aix, are similar to those discovered some years ago, by M. Borda, near Dax in Gascony. The teeth discovered at Aix, by the description given of them, seem to resemble those found at Dax, of which an under jaw is still preserved. This jaw unquestionably belongs to a large fish. . . . . I must, therefore, conclude, that the bones in the quarry of Aix are similar to those discovered at Dax; . . . . and that these bones, whatever they are, should be referred to the skeletons of fishes rather than to those of man. . . . .

"One of the heads in question was about seven and a half inches long by three and some lines broad. Its figure is that of an oblong globe, flat at the base, thicker at the posterior than the anterior end, and divided in the broadest part by seven or eight bands from seven to twelve lines wide. Each band is likewise divided into two equal parts by a slight furrow. The bands extend from the base to the summit. Those of one side are separated from those of the other by another and deeper furrow, which gradually enlarges from the anterior to the posterior part.

" From this description we cannot recognise the mould of a human head. The bones of a man's head are not divided into bands. The human head is composed of four principal bones, the figures of which appear not in the mould above described. It has not an anterior crest which extends longitudinally from the anterior to the posterior part, and divides into two equal parts, which might give rise to the furrow on the superior part of the stony mould.

" These considerations induce me to think, that this substance is rather the body of a nautilus than a human head. There are nautili actually divided into bands or bucklers like this mould. They have a channel or furrow which runs along the whole curvature, and divides them into two, from which the stony furrow might derive its origin *," &c.

I am persuaded, as well as M. le Baron de Lonjumeau, that these heads never belonged to men, but to animals of the seal kind, to sea-otters and to sea-lions or bears. It is not at Aix or Dax alone, that the heads and bones of these animals are found in rocks and caverns. His highness the present prince Marcgrave of Anspach, who to great affability unites a remarkable taste for knowledge, has been so obliging as to give me, for the Royal Cabinet, a collection of bones from the caverns of Gaillenrente in his Marcgraviate of Bareith. M. Daubenton has compared these bones with those

* Mem. de l'Acad. des Sciences, ann. 1760, p. 209—218.

of the common bear, from which they differ only by being larger. The head and teeth are longer and thicker; and the muzzle is longer and more protuberant than in our largest bears. In this collection, with which this noble prince has enriched our cabinet, there is a head which naturalists have denominated, *the head of M. de Buffon's small seal;* but, as we know not the form and structure of the heads of sea-lions, bears, and large and small seals, we shall suspend our judgment concerning the animals to which these fossil bones have appertained.

I will insist no longer upon the varieties in the composition of new strata. It is sufficient to have shown that they have been produced by no other cause than the waters which run or are stagnant upon the surface, and that they are neither so hard nor so solid as the ancient strata which were formed under the waters of the ocean.

PROOFS

OF THE

THEORY OF THE EARTH

ARTICLE XIX.

Of the Changes of Land into Sea, and of Sea into Land.

FROM what has been remarked in article i. vii. viii. and ix., it is apparent, that the terrestrial globe has undergone some great and general changes; and it is equally certain, from what has been delivered in the other articles, that the surface of the earth has suffered particular alterations. Though we are not sufficiently acquainted with the order or succession of these particular changes, we know the principal causes by which they were produced. We can even distinguish their different effects; and, if we were able to collect all the facts which natural and civil history afford concerning the revolutions that have happened on the surface of the earth, our theory would unquestionably receive

additional supports, and would be rendered still more satisfactory.

One of the principal causes of these revolutions is the motion of the sea, which has continued invariably the same in all ages; for, as the sun, the moon, the earth, the waters, the air, &c., have existed from the moment of creation, the effects of the tides, of the motion of the sea from east to west, of the currents, and of the winds, must have been felt for an equal time: and, even supposing the axis of the globe to have formerly had a different inclination, and that the continents, as well as the seas, were differently disposed, the motions of the ocean, and the causes and effects of the winds, would have remained unaltered. In whatever part of the globe the immense quantities of water which fill the ocean were collected, they would be subject to the same motions.

It was no sooner suspected that our continent might formerly have been the bottom of the sea, than the fact became incontestible. The spoils of the ocean found in every place, the horizontal position of the strata, and the corresponding angles of the hills and mountains, appeared to be convincing proofs; for, when we examine the plains, the valleys, and the hills, it is apparent, that the surface of the earth has been figured by the waters. When we descend into the bowels of the earth, it is equally evident, that those stones which include sea shells have been formed by sediments deposited by the waters, since the sea shells themselves are impregnated with the

same matter that surrounds them. And, in fine, if we consider the corresponding angles of the hills and mountains, we cannot hesitate in pronouncing, that they received their configuration and direction from currents of the ocean. It is true, that, since the earth was first left uncovered with water, the original figure of its surface has been gradually changing: the mountains have diminished in height; the plains have been elevated; the angles of the hills have become more obtuse; those bodies which have been rolled along by the rivers have received a roundish figure; new beds of tufa, of soft stone, of gravel, &c., have been formed. But every thing has remained essentially the same. The ancient form is still recognisable; and I am persuaded, that every man may be convinced, by his own eyes, of the truth of all that has been advanced on this subject; and that, whoever has attended to the proofs I have given, must be fully satisfied, that the earth was formerly under the waters of the ocean, and that the surface, which we now behold, received its configuration from the currents and movements of the sea.

We formerly remarked, that the principal motion of the sea is from east to west. The ocean, accordingly, seems to have gained from the eastern coasts both of the Old and the New Continent, a space of no less than 500 leagues. For the proofs, we must refer to art. ix., and shall here only add, that the direction of all straits, which join two seas, is from east to west. The straits of Magellan, of Frobisher, of Hudson, of Ceylon, of

the sea of Corea, and of Kamtschatka, lie all in this direction, and appear to have been formed by the irruption of the waters, which, being forcibly pushed from east to west, have opened these passages, where the waters still preserve a stronger current in this than in any other direction; for, in all straits of this kind, the tides are high and violent; but, in those situated on the western coasts, as that of Gibraltar, of Sunda, &c., the motion of the tides is almost imperceptible.

The inequalities at the bottom of the sea change the direction of the motion of the waters. These inequalities have originated from sediments and matters transported by the tides, or by other movements in the water: the tides are the principal and first, though not the only cause, which produced these inequalities. The wind is another cause; though its action begins at the surface, it agitates the whole mass to the greatest depths, as appears from particular bodies which are detached from the bottom of the sea, and thrown ashore during violent storms only.

It has already been mentioned, that, between the tropics, and even some degrees beyond them, an east wind perpetually blows. This wind, which assists the general motion of the sea from east to west, is as ancient as the tides; because it is occasioned by the rarefaction of the air produced by the heat of the sun. There are two combined causes, therefore, the operation of which is greatest in the equatorial regions: 1st, The tides, which are greatest in the southern lati-

tudes; and, 2d, The east winds, which constantly reign in these climates. These two causes have concurred, from the first formation of the earth, in producing a motion in the waters from east to west, and in agitating them more violently in this region of the globe than in any other. It is for this reason that we find between the tropics the greatest inequalities upon the surface of the earth. That part of Africa which lies between these circles, is nothing but a group of different chains of mountains, which generally extend from east to west, as appears from the direction of the great rivers that traverse this unknown region. The same observation holds with regard to the countries both of Asia and America, which lie between the tropics.

The general motion of the sea from east to west, combined with the tides, currents, and winds, produce a variety of effects, both on the bottom of the ocean and on the coasts. Varenius thinks it extremely probable, that gulfs and straits have been formed by reiterated efforts of the ocean against the land; that the gulfs of Arabia, of Bengal, and of Cambaya, have been produced by irruptions of the waters, as well as the straits between Sicily and Italy, between Ceylon and India, between Greece and Eubœa, &c.; that the probability of such irruptions, and of certain lands having been deserted by the sea, is strengthened by the scarcity of islands in the middle of great seas, and by their never appearing there in groups; that, in the immense space occupied by the Pacific Ocean, there are only two or three

small islands near the centre of it; and that, in the vast Atlantic Ocean between Africa and Brasil, we find only the small islands of St. Helena and Ascension: but all islands lie near large continents, as those of the Archipelago, which approach the continents both of Europe and Asia; the Canaries are near Africa; the Indian islands lie near the eastern part of the continent of Asia; the Antilles lie off the coast of America; and the Azores alone lie at a considerable distance both from Africa and America.

The popular tradition among the inhabitants of Ceylon, that their island had been separated from the peninsula of India by an irruption of the sea, is extremely probable. The great number of rocks and shoals between the island of Sumatra and the continent demonstrate their former union. The Malabarians affirm, that the Maldiva islands once made a part of the continent of India; and, in general, we may believe, without hesitation, that all the eastern islands have been separated from continents by irruptions of the ocean *.

The island of Great Britain appears to have been formerly a part of the continent; and that England was once joined to France, the narrowness of the strait, and the sameness of the strata of stone and of earth, on the opposite sides, are a sufficient indication. "If we suppose," says Dr. Wallis, "that France was connected to England

* See Varen. Geogr. p. 203, 217, and 220.

by an isthmus between Calais and Dover, two tides would necessarily strike with violence against each side of it twice every twenty-four hours; and the operation of the sea, both on the east and west of this isthmus, would, in the course of time, gradually cut through such a narrow neck of land. The tides, acting with violence not only against this isthmus, but also against the coasts of France and of England, must have carried away vast quantities of earth, sand, and clay, from every part on which the waves exerted their fury. Their course, however, being interrupted by the isthmus, they would not, as might be imagined, deposit their sediments upon its shores, but would transport and deposit them on the great plain which now forms the marsh of Romney, and is four miles broad and eight long; for no man, who has ever seen this plain, can possibly doubt of its having been formerly covered with the sea, as, without the intervention of the dikes of Dimchurch, a great part of it would still be overflowed by the spring tides.

"The German Sea would act in the same manner against this isthmus and against the coasts of England and Flanders, and would carry its sediments into Holland and Zeland, the soil of which was formerly under the waters, though it is now elevated forty feet above them. On the English coast, the German Sea must have occupied that large valley which commences at Sandwich, runs by Canterbury, Chatham, Chilham, and terminates at Ashford, a space of more than

twenty miles. Here the land is much more elevated than it was in ancient times; for, at Chatham, the bones of an hyppopotamos were found buried at the depth of seventeen feet, and likewise anchors of ships and sea shells.

" Nothing is more apparent than that new lands are formed by the earth, sand, clay, &c., transported and deposited by the sea: for, in the island of Okney, which is adjacent to the marshy coast of Romney, there was a flat space of ground in continual danger of being overflowed by the river Rother; but this flat, in less than sixty years, has been considerably elevated by the accession of fresh matter brought in by every tide. This river has, besides, deepened its channel so much, that its mouth, which, less than fifty years ago, was fordable by men, is now capable of receiving large vessels.

" In the same manner has the bank of sand, which runs obliquely from the coast of Norfolk to that of Zeland, been formed. This bank is the place where the German and French seas encounter since the rupture of the isthmus; and it is here that the waters deposit the earth and sand which they carry off from the coasts. It is even probable that this bank of sand may, in a succession of ages, give rise to a new isthmus *."

" It is extremely probable," says Mr. Ray, " that the island of Great Britain was formerly joined to France: whether it was separated by an earth-

* See Phil. Trans. abridg. vol. iv. p. 227.

quake, by an irruption of the ocean, or by the operation of men, we know not. But the former junction of Britain to the continent is apparent from the identity of the rocks and different strata, at the same elevation, on the opposite coasts; and from the similar extent of the rocks on each side, being both about six miles. The narrowness of this strait, which exceeds not twenty-four English miles, and its shallowness, when compared to the depth of the neighbouring sea, render it probable that England has been separated from France by some accident. To these proofs we might add, that wolves and bears formerly existed in this island: it is not probable that these animals could swim over, nor that such destructive creatures would be transported by men; for, in general, the noxious animals of the continent are found in all those islands which are very near it, but never in those that are remote. This fact was remarked by the Spaniards when they arrived at America *."

In the reign of Henry I. of England, a part of Flanders was overflowed by an irruption of the sea. In 1446, more than 10,000 persons were drowned by a similar irruption in the territory of Dordrecht, and more than 100,000 round Dullart in Friseland and Zeland. In these two provinces, above 300 villages were overflowed. The tops of their towers and spires are still visible above the surface of the water.

From the coasts of France, England, Holland,

* See Ray's Discourses, p. 208.

and Germany, the sea has in many places retreated. Hubert Thomas, in his Description of the Country of Liege, assures us, that the walls of the city of Tongres were formerly surrounded by the sea, though it is now thirty-five leagues distant from that city. He gives several satisfactory reasons; among others, he informs us, that, in his time, the iron rings, to which ships were fastened, still remained in the walls. The fens of Lincoln, of the island of Ely, and the Crau of Provence in France, may be regarded as lands abandoned by the sea, which has likewise, since the year 1665, retired considerably from the mouth of the Rhone. At the mouth of the Arno, in Italy a large quantity of land has been gained from the sea: and Ravenna, which was formerly a harbour, is no longer a sea-port. The whole of Holland appears to be new land: the surface of the ground is nearly on a level with the sea, although it has received daily elevations from the mud and earths transported by the Rhine, the Maese, &c.; for the soil of Holland was formerly, in many places, computed to be fifty feet below the level of the sea.

It has been alleged, that, in the year 860, a furious tempest drove such quantities of sand upon the coast, that the mouth of the Rhine near Catt was entirely blocked up; and that this river overflowed the whole country, overturned trees and houses, and at last emptied itself into the channel of the Maese. In 1421, another inundation separated the city of Dordrecht from the main land, overwhelmed seventy-

two villages, and drowned 100,000 persons, beside a vast number of cattle. The dike of Issel was broken down in 1638, by the ice from the Rhine blocking up the passage of the water, which occasioned an opening in the dike of several fathoms, and a great part of the province was laid under water before the breach could be repaired. The province of Zeland, in 1682, suffered a similar inundation, which drowned more than thirty villages; and an amazing number of men and cattle perished, as the unfortunate event happened during the night. The loss would have been still greater, had not a south-east wind opposed the motion of the waves; for there was such a swell in the sea, that the water rose eighteen feet above the highest ground in the province *.

The harbour of Hithe, in the county of Kent, is entirely blocked up, notwithstanding much labour and expense bestowed, on different occasions, to clear it from rubbish. For several miles round, we find an astonishing quantity of shells and other sea bodies, which had been accumulated in ancient times, and which are now covered with soil, and afford excellent pasturage. The sea, on the other hand, often encroaches upon the land. The lands of Goodwin, for example, which formerly belonged to a nobleman of that name, are now converted into sands, and are covered with the waters of the ocean. Thus the sea gains upon some coasts, and loses

* See les Voyag. hist. de l'Europe, tom v. p. 70.

upon others, according to their different situations and circumstances *.

Upon Mount Stella, in Portugal, there is a lake, in which are found the wrecks of ships, though this mountain is twelve leagues distant from the sea †. Sabinius, in his commentary upon Ovid's Metamorphoses, tells us, that, in the year 1460, a ship, with its anchors, was found in one of the Alpine mines.

These changes of sea into land, and of land into sea, are not peculiar to Europe. The other parts of the globe, if properly investigated, would furnish more striking and numerous examples.

Calecut was formerly a celebrated city, and the capital of a kingdom of that name. It is now reduced to an inconsiderable town, ill built, and almost deserted. The sea, which, for a century past, has gained greatly upon this coast, now covers most of the ancient city. Ships moor upon its ruins, and the port is choked up with a number of rocks, upon which many vessels have been wrecked ‡.

The province of Jucatan, a peninsula in the gulf of Mexico, was formerly a part of the sea. This neck of land stretches about 100 leagues in length, and is no where above twenty-five leagues broad. The air is hot and moist. The earth furnishes plenty of water, though, in so large a country, there are neither rivers nor brooks; and, when pits are dug, such multitudes

* See Phil. Trans. abridg. vol. iv. p. 234.

† See Gordon's Geog. Gram. p. 149.

‡ See Lettres Edifiantes, recueil ii. p. 187.

of shells every where appear, as leave no room for doubting that this whole tract of land was formerly a part of the ocean.

It is a tradition among the inhabitants of Malabar, that the Maldiva islands originally belonged to the continent of India, and that they were detached from it by the violence of the ocean. The number of these islands is so great, and they are separated by such narrow channels, that the bowsprits of vessels, in passing, drive off leaves from the trees on each side; and, in some places, a vigorous man, by laying hold of a branch, may leap into another island *. The cocoa trees, found at the bottom of the sea, are a farther proof that the Maldivas formerly belonged to the continent.

The island of Ceylon, those of Rammanakoiel, and many other islands, it is believed, were also disjoined from the continent by currents, which, in many places of the Indian Sea, are extremely rapid †. It is certain, however, that the sea has encroached thirty or forty leagues on the north-east coast of Ceylon.

The sea appears to have lately abandoned many of the promontories and islands of America. We have already remarked, that the territory of Jucatan is full of shells. The same phænomenon takes place in the low grounds of Martinico and the other Antilles. The inhabitants distinguish

* See Voyages des Hollandois aux Indes Orientales, p. 274.

† Ibid. vol. iv. p. 485.

the earth below the surface by the name of *lime*; because they make lime of the shells, great banks of which lie immediately under the vegetable soil *.

There are some lands which the sea alternately covers and leaves bare, as happens in several islands of Norway, Scotland, the Maldivas, the gulf of Cambaya, &c. The Baltic Sea has gradually gained a great part of Pomerania; and it has covered and destroyed the celebrated port of Vineta. In the same manner, the Norwegian Sea has advanced into the continent, and formed several islands. The German Sea has encroached upon Holland, near Catt, to such a degree, that the ruins of an ancient Roman citadel, which was formerly situated on the coast, lie now at a considerable distance in the sea. The marshy ground in the island of Ely, and the Crau of Provence, are, on the contrary, lands which the sea has deserted. The Downs have been formed by accumulations of sand, earth, and shells successively driven upon the coasts by winds blowing from the sea. For example, on the west coasts of France, Spain, and Africa, a violent west wind reigns, by which the waters are pushed with violence against the shores; and downs, accordingly, are frequent on these coasts. The east winds, in the same manner, when they continue long, drive the waters so forcibly from the coasts of Syria and Phœnicia, that large chains of rocks,

* See Nouv. Voyages aux Isles de l'Amerique.

which are covered during the west winds, are left dry. Besides, downs are not composed of stones and marble, like the mountains which have been formed in the bottom of the ocean, because they have not remained long enough under the waters. That the waters of the sea possess a petrifying power, and that the stones formed in the earth are very different from those formed at the bottom of the ocean, is fully evinced in my discourse on minerals.

In traversing the coasts of France, we perceive that a part of Brittany, Picardy, Flanders, and Lower Normandy, have very recently been deserted by the sea; because, through all this extent of country, we still find great quantities of oysters, and other shells, in their natural state. We are certain, from experience, that, for a century past, the sea has been retiring from the coast of Dunkirk. When the moles of this port were constructing, in the year 1670, the fort of Good Hope, which terminates one of these moles, was built upon piles a great way beyond the low water mark. But, at present, the water never advances nearer this fort than 300 fathoms. In 1714, when the new harbour of Mardik was deepening, the moles were likewise carried beyond the low water mark; but now, when the tide is ebb, there is a dry space of more than 500 fathoms. If the sea continues thus gradually to retire, Dunkirk, like Aiguemortes, will, in a few centuries, be no longer a sea-port. If the sea has lost ground so considerably in our times,

how far must it have retired since the beginning of the world? *

The bare inspection of Saintonge is sufficient to convince us, that it was formerly covered by the sea. The ocean having abandoned these lands, the Charente followed as the waters retired, and formed a river where formerly there was only a great lake or morass. The country of Aunis, which was anciently covered by the sea and stagnant waters, is one of the most recent lands of France. It is even probable that this territory was a morass about the end of the fourteenth century †.

It appears, therefore, that the ocean, during some centuries, has retired many feet from all our coasts; and, if we examine those of the Mediterranean, from Roussillon to Provence, we shall find that this sea has likewise retreated nearly in the same proportion. These facts render it evident, that the circumference of all the coasts of Spain and Portugal, as well as those of France, is greatly extended. The same observation has been made with regard to Sweden, where some philosophers have conjectured, that, in the course of 4,000 years, the Baltic, the depth of which exceeds not thirty fathoms, will be totally abandoned by the waters.

If similar observations were made in every

* Mem. pour la Subdelegation de Dunkerque, relativement à l'Hist. Nat. de ce Canton.

† Extrait de l'Hist. de la Rochelle, art. ii. et iii.

country, I am persuaded, that, in general, the sea would be found to have retired from every coast. The same causes which produced its first retreat and successive sinking, are not absolutely annihilated. In the beginning, the sea was 2,000 fathoms above its present level. The immense swellings on the surface of the globe, which first subsided, made the waters sink, at first rapidly, and afterwards in proportion as the more inconsiderable caverns gave way. The sea, of course, was proportionally depressed; and, as many caverns still exist, which must, from time to time, sink, either by the action of volcanos, by the force of water, or by earthquakes, we may with certainty predict, that the ocean will continue to retire, and, consequently, that the extent of all our continents will be gradually augmented.

Since finishing my Theory of the Earth, which was composed in the year 1744, I have perused M. Barrere's Dissertation on the Origin of figured Stones. It gave me peculiar satisfaction to find that the ideas of this accomplished naturalist, concerning the formation of downs, and the duration of the sea upon the surface of the earth which we inhabit, exactly corresponded with my own. Aiguismortes, which is now more than a league and a half from the sea, was a port in the time of St. Louis. Psalmodi was an island in the year 815; and it is now more than two leagues from the sea. The same change has happened at Maguelone. The greatest part of the vineyard of Agde was covered, about

forty years ago, with the waters of the sea. In Spain, the sea, within these few years, has retired considerably from Blanes, from Badalona, from the environs of the river Vobregat, from Cape Tortosa, along the coast of Valencia, &c.

The sea may form hills and mountains, 1. By transporting earth, slime, sand, and shells from one place to another. 2. By depositing sediments composed of small particles detached from the bottom and from the coasts. And, *lastly*, hills and downs may be formed by sand and other particles driven against the coasts by particular winds; these are gradually deserted by the sea, and become parts of the dry land. The downs of Flanders and Holland are of this kind. They consist of small elevations or hills, composed of sand and shells which have been blown from the sea upon the coasts. M. Barrere gives another example, which merits observation. "The sea," he remarks, "by its motion, detaches immense quantities of plants, sand, shells, and slime, from its bottom, which are continually pushed by the winds and the waves towards the coasts. The perpetual repetition of this operation must give rise to gradual accumulations of new strata, which elevate the earth, produce downs and hills, enlarge the land, and confine the sea within narrower bounds.

"It is apparent that new strata of different materials must have been formed by the constant attrition of the waters, by the deposition of sediments, and by other causes, the operation of which has been coëval with the existence

of the globe itself. Of this we have a remarkable proof in the different strata of fossil shells, and other sea bodies, found at Roussillon near the village of Naffiac, which is seven or eight leagues from the sea. These beds of shells, which incline at different angles from west to east, are divided from each other by strata of earth and sand sometimes of a foot and a half, and sometimes of two or three feet in thickness. In dry weather they seem as if sprinkled over with salt, and form a chain of hillocks, from twenty-five to thirty fathoms high. A long chain of hillocks of such a height could not be formed at once, but gradually, and by a long succession of time. Effects somewhat similar might have been produced by an universal deluge. But, in this case, the different beds of fossil shells, instead of preserving a regular form, would have been blended together without any order."

I entirely agree with the sentiments of M. Barrere, except as to the formation of mountains, which cannot be ascribed solely to those causes which increase the land and diminish the boundaries of the ocean. On the contrary, I can produce several convincing arguments to prove, that most of those eminences, which appear on the surface of the earth, have actually received their original formation in the sea itself: 1. Because they have corresponding angles, which necessarily imply the cause we have assigned, namely, the motion of the currents. 2. Because downs and hills, which have originated

from materials thrown upon the coasts, are not, like common hills, composed of marble and hard stones. Besides, the shells found in the former are only in the fossil state; but those in the latter are entirely petrified. Neither is the position of the strata equally horizontal in downs, as in the hills composed of marble and hard stone. They are more or less inclined, as in the hills of Naffiac. On the contrary, in the hills and mountains formed by sediments under the waters of the sea, the strata are always parallel, and often horizontal; and the shells and other matter of them are completely petrified. I despair not of being able to prove, that the marbles and other calcarious bodies, which are almost all composed of madrepores, astroites, and shells, have acquired their density and perfection at the bottom of the ocean. But the tufas, soft stones, incrustations, stalactites, &c., which are likewise calcinable, and have been formed since the earth was left dry, can never acquire the degree of density and of petrifaction peculiar to marble and other hard stones.

The remarks of M. Saulmon, concerning the *galets*, which are found in many places, may be seen in the History of the French Academy, *anno* 1707. These galets are round, flat, finely polished pieces of flint, thrown out by the sea upon the coasts. At Bayeux, and at Prutel, which is a league from the sea, galets are found in digging pits and wells. The mountains of Bonneuil, of Broie, and of Quesnoy, which are eighteen leagues distant from the sea, are co-

vered with galets. They are also found in the valley of Clermont in Beauvois. M. Saulmon farther informs us, that a hole, sixteen feet in length, was pierced horizontally into the high beach of Tresport, which consists of a soft earth; and that, in the space of thirty years, it was entirely obliterated by the sea. Supposing the sea to encroach uniformly upon this shore, it will gain half a league in 12,000 years.

The motions of the sea, therefore, must be regarded as the principal cause of all those changes which have already happened, and of those which are daily produced upon the surface of the earth. But there are other causes, which, though less considerable, have some effect in changing the superficial parts of this globe. The rivers, the brooks, the melting of snows, the torrents, the frosts, &c., have given rise to many alterations. The rains have diminished the height of the mountains; the rivers and brooks have elevated the plains, and dammed up the sea at their mouths; the torrents and the melting of snows have scooped out deep ravines or furrows in the valleys and narrow passages between the mountains; the frosts have split rocks, and detached them from their original stations: innumerable examples of revolutions produced by all these causes might be given. Varenius tells us, that the rivers transport into the sea vast quantities of earth, and deposit them at greater or lesser distances from the shore, in proportion to the rapidity of their currents. These portions

of earth fall to the bottom, and first form small banks, which, by constant accessions, become shoals, and at last appear in the form of fertile and habitable islands. It is in this manner that the islands in the Nile, those in the river St. Lawrence, the island of Landa, situated near the mouth of the river Coanza, on the coast of Africa, the Norwegian islands, &c., have received their existence *. To these may be added the island of Trong-ming in China, which has been gradually formed by matters brought down by the river Nankin, and deposited near its mouth. This island is more than twenty leagues in length, and from five to six in breadth †.

The Po, the Trento, and other rivers of Italy, bring down such quantities of earth into the *lagunes* of Venice, especially in the time of inundations, that they must be gradually filled up. Many parts of them are already dry during the ebb tide; and there is in them no depth of water, except in the canals, which are supported at an immense expense.

Large sand-banks are thrown up at the mouths of the Nile, of the Ganges, of the Indus, of the Plata, and of many other rivers. La Loubere, in his voyage to Siam, informs us, that the banks of sand and of earth augment daily at the mouths of the great rivers of Asia, and to such a degree, that the navigation of them

* See Varen. Geogr. p. 214.

† See Lettres Edifiant. rec. xi. p. 234.

becomes every hour more difficult, and will soon be impracticable. The same observation applies to the great rivers of Europe, and especially to the Wolga, which empties itself by more than seventy mouths into the Caspian, and to the Danube, which runs into the Black Sea by seven mouths, &c.

As it seldom rains in Egypt, the regular inundations of the Nile proceed from the torrents which fall into it from Ethiopia. It brings down vast quantities of mud, which it deposits annually not only upon the soil of Egypt, but throws it to great distances into the sea, where it is laying the foundations of a new country, which must arise, in the course of time, out of the bosom of the ocean; for, upon sounding at the distance of twenty leagues from the coast, the mud of the Nile is found at the bottom of the sea; and every year it receives fresh accumulations. The Lower Egypt, now called the Delta, was formerly a bay *. Homer tells us, that the island of Pharos was a day and a night's voyage from Egypt; and now it is almost contiguous to the land. The soil of Egypt is not every where of an equal depth; it grows thinner the farther we remove from the sea. Near the banks of the Nile, there are sometimes more than thirty feet of good soil; but at the extremity of the inundation, there are not, perhaps, above seven

* See Diodor. Sic. lib. iii. Aristot. de Meteor. lib. i. cap. 14. Herodot. § 4, 5, &c.

inches. All the cities of the Lower Egypt have been built upon artificial eminences *. The town of Damietta, which is now ten miles from the sea, was a part of the ocean in the year 1243. The town of Fooah, which, 300 years ago, was situated at the mouth of the Canopic branch of the Nile, is now seven miles distant from it. Within forty years, the sea has retired half a league from Rosetta, &c. †

Many changes have also taken place at the mouths of the great rivers of America, and even in those which have been but lately discovered. Charlevoix tells us, "that at the mouth of the Missisippi, below New Orleans, the land runs out into a point, which appears not to be very ancient; because, wherever the earth is dug, plenty of water is found; and besides, the many little islands, which have recently appeared in all the mouths of this river, leave no room to doubt that this point of land was formed in the same manner. It is certain," says he, "that when M. Salle sailed down the Missisippi to the sea, the mouth of this river was considerably different from what it is now.

"The nearer," he adds, "we approach the sea, this difference becomes the more conspicuous. There is no water in most of the small channels cut in the bar by the river. These channels are greatly multiplied by the trees brought down by the current. A single tree, with its branches

* See Shaw's Travels. † Ibid.

and roots, when stopped in a shallow part of the river, will entangle a thousand. I have seen," says he, "200 leagues from New Orleans, different collections of trees, any one of which would fill all the wood-yards in Paris. Nothing can disentangle them. The mud brought down by the river serves as a cement, and gradually covers them. Every inundation leaves a new stratum; and, in a few years, plants and shrubs begin to grow." It is in this manner that most points of land and islands, which so often change the course of rivers, are originally produced.

All the revolutions, however, produced by rivers, are very slow, and become not considerable till after a long course of years. But those which are occasioned by inundations or earthquakes are sudden and almost instantaneous. According to the Timæus of Plato, we are assured, by the ancient priests of Egypt, 600 years before the birth of Christ, that there existed an island beyond the Pillars of Hercules, called Atlantis, which was larger than both Asia and Lybia taken together; and that this great island was sunk under the waters of the ocean by a terrible earthquake. "Traditur Atheniensis civitas restitisse olim innumeris hostium copiis quæ, ex Atlantico mari profectæ, propè cunctam Europam Asiamque obsederunt; tunc enim fretum illud navigabile, habens in ore et quasi vestibulo ejus insulam quam Herculis Columnas cognominant: ferterque insula illa Lybiâ simul et Asiâ

Major fuisse, per quam ad alias proximas insulas patebat aditus, atque ex insulis ad omnem continentem è conspectu jacentem vero mari vicinam; sed intrà os ipsum portus angusto sinu traditur, pelagus illud verum mare, terra quoque ille verè erat continens, &c. Post hæc ingenti terræ motu jugique diei unius et noctis illuvione factum est, ut terra dehiscens omnes illos bellicosos absorberet, et Altantis insula sub vasto gurgite mergeretur."—*Plato in Timæo.* This ancient tradition is not devoid of probability. The lands swallowed up by the waters were, perhaps, those which united Ireland to the Azores, and the Azores to the continent of America; for, in Ireland, there are the same fossils, the same shells, and the same sea bodies, as appear in America, and some of them are found in no other part of Europe.

Two evidences are mentioned by Eusebius on the subject of deluges: the one is Melo, who affirms, that all the plains of Syria were formerly laid under water: the other is Abidenus, who says, that, in the reign of king Sisithrus, there was a great deluge, which had been predicted by Saturn. Plutarch, *De Solertia Animalium,* Ovid, and other mythologists, describe the deluge of Deucalion, which happened, they say, in Thessaly, about 700 years after the universal deluge. It is also alleged, that there was a still more ancient deluge in Attica, during the time of Ogiges, about 230 years before that of Deucalion. In the year 1095, a deluge in Syria

drowned a prodigious number of people*. In 1164, a deluge in Friesland covered the whole environs of the coasts, and drowned several thousands of the inhabitants†. Another inundation, in 1218, destroyed 100,000 men. Of inundations there are many other examples.

Impetuous winds may be regarded as a third cause of changes on the surface of the globe. They not only give rise to downs and hills along the sea-coasts, but they often arrest rivers, make them regorge, and change their directions. They carry off cultivated lands, tear up trees, overturn houses, and cover whole countries with sand. Upon the coast of Brittany, in France, we have an example of these inundations of sand: the History of the Academy, *anno* 1722, describes it in the following terms:

"In the environs of St. Paul de Leon, in Lower Brittany, there is a province on the sea-coast, which, before the year 1666, was inhabited; but now is totally deserted, on account of the sand, which has covered it to the depth of twenty feet, and which daily gains ground. Reckoning from the above period, the sand has advanced about six leagues into the country; and it is now within half a league of St. Paul, and that town must probably soon be deserted. The tops of steeples, and of some chimneys, still appear above this ocean of sand. The inhabitants, however, have always had leisure to quit their possessions in safety." p. 7.

* See Alsted. Chron. chap. 25. † See Krank, lib. v. c. 4.

"This calamity is augmented by an east, or a north wind, which elevates this fine sand, and carries it in such quantities, and with such rapidity, that M. Deslandes, to whom the Academy are indebted for the observation, when walking in this country during an east wind, found himself obliged to shake his hat and his garments from time to time, on account of the great weight of sand with which they were loaded. Besides, when the wind is violent, it carries the sand over a small arm of the sea, as far as Roscof, a port much frequented by foreign vessels; and the sand accumulates in the streets of this village to the height of two feet, which obliges the inhabitants to drive it off in waggons. It may be farther remarked, that the sand is mixed with ferruginous particles, which are recognisable by the magnet.

"The coast which furnishes this sand extends from St. Paul to Plouefcat, a space of more than four leagues; and it is nearly on a level with the sea when the tide is full. It is situated in such a manner that the east and north-east winds only can blow the sand in upon the country. It is easy to conceive how sand carried and accumulated into any place by the wind, may again be taken up by the same wind, and carried still farther. Thus the sand may continue advancing, and covering new land, as long as the magazine from which it originally proceeds shall remain unexhausted; for, if the fountain were once dried up, the sand, by advancing, would diminish in depth, and its destructive

consequences would gradually decay. But it is not improbable that the sea may long continue to supply fresh sand, and keep this baneful magazine in a condition to do perpetual mischief.

"This disaster is not of an old date. Perhaps it was not till lately that the place was sufficiently stored to allow great quantities of sand to be carried off; or, perhaps, it has but recently been left uncovered by the waters. This coast has undergone some change. At present, the sea, at full tide, reaches half a league on this side of certain rocks, which it formerly never passed.

"This miserable province justifies what has been related, both by ancient and by modern travellers, that whole cities, and even vast armies, have been buried by tempests of sand in the deserts of Arabia."

Mr. Shaw relates, that the ports of Laodicea, Tortosa, Rowadsa, Tripoly, Tyre, Acra, and Jaffa, are blocked up with sand transported by the high waves which rise on that part of the coast of the Mediterranean, when the west wind blows with violence *.

It is needless to give more examples of alterations on the surface of this globe. The fire, the air, and the waters, produce continual changes, which, in a succession of ages, become considerable. The sea and the land not only change places from the effects of general and

* See Shaw's Travels.

stated periodic laws, but a number of revolutions are occasioned by particular and accidental causes, as earthquakes, inundations, sinkings of mountains, &c. Thus the surface of the earth, which we regard as the most permanent of all things, is subjected, like the rest of nature, to perpetual vicissitudes.

CONCLUSION.

FROM the proofs delivered in art. vii. and viii., it appears to be an established fact, that the whole surface of what is now dry land, was formerly buried under the waters of the ocean. It is equally clear, from art. xii., that the flux and reflux, and other movements of the ocean, perpetually detach from the coasts, and from the bottom of the sea, shells, and matter of every species; and that these are deposited in other places in the form of sediments, and give rise to the horizontal strata which every where appear. In the ixth art. we have proved, that the inequalities on the surface of the globe have been occasioned by the motion of the waters of the sea; and that the mountains received their original formation from successive accumulations of sediments. It is likewise evident, from art. xiii., that the currents, which first followed the direction of these inequalities, afterwards bestowed on them their present figure, namely, their alternate and corresponding angles. From art. viii. and xviii. it appears, that most of the matters detached from the coasts

and from the bottom of the sea, were, when deposited in sediments, in the form of a fine impalpable powder, which entirely filled the cavities of shells, whether this powder was of the same nature, or only analogous to the matter of which the shells were composed. It is undeniable, from art. xvii., that the horizontal strata, which have been formed by successive accumulations of sediments, and which at first were soft and ductile, acquired density and compactness in proportion as they dried; and that the perpendicular fissures in the strata derived their origin from the act of drying.

After perusing art. x. xi. xiv. xv. xvi. xvii. xviii. and xix. we must be convinced, that the surface of the earth has been disfigured by many revolutions and particular vicissitudes, arising from the operation of the waters, and the effects of rains, frost, rivers, winds, subterraneous fires, earthquakes, inundations, &c., and, consequently, that the sea has alternately changed places with the dry land, especially in the first ages after the creation, when terrestrial substances were much softer than they are at present. It must, however, be acknowledged, that our judgment concerning the succession of natural revolutions cannot fail to be very imperfect; that we are still less competent judges of those changes which owe their birth to fortuitous events; and that the defect of historic records deprives us of the knowledge of particular facts. We desiderate both time and experience. We

never consider, that, though our existence here be extremely limited, Nature proceeds in her course. We are ambitious of condensing into our momentary duration both the past and the future, without reflecting that human life is only a point of time, a single fact in the history of the operations of God.

FACTS AND ARGUMENTS

IN SUPPORT OF THE

COUNT DE BUFFON'S

EPOCHS OF NATURE.

THE treatise composed by the count de Buffon, under the title of *Les Epoques de la Nature*, is exceedingly ingenious. It is intended to establish, by facts and reasoning, his Theory of the Formation of the Planets*. But as this theory, however it may be relished on the continent, is perhaps too fanciful to receive the general approbation of the cool and deliberate Briton, the translator has been advised not to render it into English. Many of the facts, however, are too important to be omitted. Instead of a regular translation, therefore, he shall give a general view only of the positions laid down in this treatise, together with the most interesting facts produced in support of these positions.

* See vol. i. p. 59 of this work.

The count de Buffon begins his subject with a preliminary discourse, in which he endeavours to unfold the different changes the terrestrial globe has undergone from its first projection out of the sun to the present time. In this discourse, the author observes the following order: 1. He mentions such facts as may lead us to the origin of nature. 2. He marks those monuments which ought to be regarded as the evidences of the first ages. 3. He collects such traditions as may convey some idea of the ages which succeeded. "After which," says he, "we shall endeavour to connect the whole by analogies, and to form a chain, which, from the commencement of time, shall descend to the present days."

FIRST FACT.

The earth is elevated at the equator and depressed at the poles, in the proportion required by the laws of gravity and of the centrifugal force.

SECOND FACT.

The earth possesses an internal heat which is proper to itself, and independent of that communicated to it by the rays of the sun.

THIRD FACT.

The heat conveyed to the earth by the sun is very small when compared with the heat proper to the globe; and this heat transmitted by the sun would not alone be sufficient to support animated nature.

FOURTH FACT.

The materials of which the earth is composed are, in general, of a vitreous nature, and the whole of them may be converted into glass.

FIFTH FACT.

We find on the whole surface of the earth, and even on the mountains, to the height of 1,500 and 2,000 fathoms, an immense quantity of shells and other relics of marine productions.

The first fact, namely, the elevation of the globe at the equator and its depression at the poles, has been mathematically demonstrated and physically proved by the theory of gravitation, and by experiments with the pendulum. The figure of the earth is precisely the same which a

fluid globe revolving round its axis with equal celerity would assume. Hence the matter of which the earth is composed was in a state of fluidity the moment it assumed its form, and this moment happened whenever it began to turn round its own axis. Now, though heat is the general cause of fluidity, since water itself, without heat, would form a solid mass, we have two methods of conceiving the possibility of the primitive fluid state of the earth. The first is the solution of terrestrial matters in water; and the second is their liquefaction by fire. But most of the solid matters of which the earth is composed are not soluble in water; and, at the same time, the quantity of water, in proportion to that of dry and solid matter, is so small, that it is impossible the one could be dissolved by the other. Of course, as this state of fluidity could not be effected by dissolution or maceration in water, this fluidity must have been produced by the operation of fire.

This conclusion assumes a new degree of probability from the second fact, and is rendered certain by the third. The internal heat of the globe, which still subsists partially, and is greater than that afforded by the sun, shows that this primitive fire is not yet nearly dissipated. The surface of the earth is colder than its interior parts. Uncontrovertible and reiterated experiments evince, that the whole mass of the globe has a heat proper to itself, and totally independent of that of the sun. This heat is rendered evident by

comparing our winters with our summers *; and it is still more palpable when we penetrate into the bowels of the earth. At equal depths, it is invariably the same, and it appears to augment in proportion as we descend.

"At no great depth, we perceive a heat which never varies with the temperature of the atmosphere. We know, that the liquor of the thermometer remains, during the whole year, at the same height in the caves of the Observatory, which exceed not eighty-four feet, or fourteen fathoms below the surface. Hence this point has been fixed as the mean temperature of our climate. This heat commonly continues nearly the same, from fourteen or fifteen to sixty, eighty, or one hundred fathoms, more or less, according to circumstances, as we experience in our mines. Beyond this depth it augments, and sometimes becomes so great, that the workmen could not support it, if they were not cooled by fresh air, either from air-pits, or from falls of water. . . . . M. de Gensanne found, that, in the mines of Giromagny, three leagues from Béfort, when the thermometer was carried fifty-two fathoms deep, it stood at ten degrees, as in the caves of the Observatory; that, at 106 fathoms deep, it stood at 10½ degrees; that, at 158 fathoms, it mounted to 15½ degrees; and that, at 222 fathoms, it rose to 18½ degrees †."

* See Suppl. tom. i. part i. and particularly the two Memoirs, sur la Temperature des Planetes, Suppl. tom. ii.

† Dissert. sur la Glace, par M. Mairan, p. 60.

"In proportion as we descend into the bowels of the earth," M. de Gensanne remarks, "we perceive a sensible increase of heat. One thousand eight hundred feet below the level of the Rhine, at Huninguen, in Alsace, I found, that the heat was so great as to produce a sensible evaporation from water. A detail of my experiments on this subject may be seen in the last edition of that excellent *Traité de la Glace* composed by my deceased illustrious friend M. Dortous de Mairan †."

"All the rich veins of every species of metal," says M. Eller, "are in the perpendicular fissures of the earth; and the depth of these fissures cannot be ascertained. In Germany, some of them have been traced above 6,000 feet deep. In proportion as the miners descend, they feel that the temperature of the air becomes always hotter †."

Though our deepest mines and pits are inconsiderable excavations, yet the internal heat is more sensibly felt in them than on the surface. We may, therefore, presume, that, if we could penetrate still deeper, this heat would increase, and that the parts near the centre of the earth are hotter than those more distant. This internal heat is likewise apparent from the temperature of the ocean, the waters of which, at equal depths, exhibit nearly the same heat as that of the interior parts of the earth. "Having plunged a ther-

* Hist. Nat. de Languedoc, tom. i. p. 24.

† Mem. sur la Generation des Metaux. Academie de Berlin, ann. 1733.

mometer," M. Marsigli remarks, "into the sea in different places and at different times, it was found that the temperature at ten, twenty, thirty, and one hundred and twenty fathoms, was equally from ten to $10\frac{3}{4}$ degrees *." On this subject M. de Mairan judiciously remarks, "that the hottest waters, which are at the greatest depth, must, as being the lightest, continually ascend above those that are heavier. Hence, according to Marsigli's observations, the temperature of this immense body of water must be always nearly equal, except near the surface, which is exposed to the impressions of the air, where the water sometimes freezes before it has time to descend by its own weight and coolness †."

Besides, it is easy to show, that the fluidity of the ocean ought not, in general, to be ascribed to the powers of the solar rays; since we learn from experience, that the light of the sun does not penetrate the most limpid water above 600 feet; and, of course, that its heat will not reach above a fourth part of that depth, or 150 feet. The late M. Bouguer, a learned astronomer of the Royal Academy of Sciences, found, that, when sixteen pieces of common glass were applied to each other, and making a thickness of $9\frac{1}{2}$ lines, the light, in passing through these sixteen pieces of common glass, was diminished 247 times. He then placed

* L'Hist. Physique de la Mer, par Marsigli, p. 16.
† Dissert. sur la Glace, p. 69.

seventy-four pieces of the same glass in a tube, and at some distance from each other. When this experiment was made, the sun was fifty degrees above the horizon. A very faint appearance of the sun's disk was still perceptible through these seventy-four pieces of glass. The persons who attended him could likewise perceive, but with difficulty, a feeble light. But, when other three pieces of glass were added to the seventy-four, none of them could distinguish the smallest vestige of light. Hence, if we suppose eighty pieces of the same glass, we have a thickness which will render it perfectly opaque.

From this analogy between the transparency of glass and water, M. Bouguer found, that, to render sea water, which is the most limpid of all waters, perfectly opaque, a thickness of 256 feet is necessary, provided, by another experiment, the light of a flambeau was diminished in the proportion of fourteen to five in traversing 115 inches of water contained in a tube of nine feet seven inches in length. Hence, according to M. Bouguer, no sensible light can pass deeper than 256 feet in water*.

It appears to me, however, that the conclusion drawn by M. Bouguer is very distant from the truth. His experiments should have been made with masses of glass of different thicknesses, and not with separate pieces applied to each other. I am persuaded that the sun's light would penetrate a greater thickness than

* Essai d'Optique sur la Gradation de la Lumiére, p. 85.

that of these eighty pieces, which formed a thickness of no more than $47\frac{1}{2}$ lines, or near four inches. Now, though these pieces he employed were of common glass, it is certain that a solid mass of the same glass, of four inches thick, would not entirely intercept the light of the sun, especially as I know, by my own experience, that light passes easily through six solid inches of white glass. I believe, therefore, that the thicknesses assumed by M. Bouguer should be more than doubled, and that the light of the sun penetrates 600 feet deep into the waters of the ocean; for there is another inaccuracy in M. Bouguer's experiments. He did not make the light of the sun pass through his tube of nine feet seven inches long: he employed the light of a flambeau, and thence concluded the diminution to be in the proportion of fourteen to five. But I am persuaded, that, if the light of the sun had been employed, this diminution would not have been so great, especially as the light of a flambeau could only pass obliquely, whilst that of the sun, by passing directly, would have penetrated deeper by its incidence alone, independent of its purity and intensity. Thus, taking all circumstances into consideration, it appears, that, to approach the truth as near as possible, we should suppose, that the light of the sun penetrates the sea to the depth of 600 feet, and that its heat reaches 150 feet deep. The light and heat must here be understood as sensible degrees only of these qualities.

That the heat of the sun penetrates not above 150 feet deep in the waters of the ocean, I ascertained by analogy, derived from an experiment which appears to be decisive. With a lens of twenty-seven inches diameter by six inches thick at the centre, I perceived, that, by covering the middle part, the lens burnt only from the circumference as far as four inches thick, and that all the thicker part scarcely produced any heat. I then covered the whole lens, except an inch round the centre, and I found, that, after passing this thickness of six inches of glass, the light of the sun had no influence on the thermometer. Hence I am warranted to presume, that this same light, weakened by 150 feet thick of water, would not produce a perceptible degree of heat.

The light proceeding from the moon is unquestionably a reflected light of the sun. This light, however, has no sensible heat, even when the rays are collected into the focus of a burning-glass. Neither would the light of the sun have any heat after passing through a certain depth of water; because it would then be equally feeble as that of the moon. I am, therefore, persuaded, that, by allowing the rays of the sun to pass through a large tube filled with water, and only fifty feet long, which is no more than a third of the depth I have supposed, this feeble light would produce no effect upon the thermometer, even though the liquor stood at the freezing point. From whence I may conclude, that, though the light of the sun pene-

trates 600 feet in the waters of the ocean, its heat would not reach one fourth part of that depth. All the waters below this point would necessarily freeze, unless there was an internal heat in the earth, which alone can maintain their fluidity. In the same manner it is proved, by experience, that the heat of the solar rays penetrates not above fifteen or twenty feet deep in the earth, since ice is preserved at these depths during the warmest summers. Hence, it is clear, that below the basin of the sea, as well as under the superior strata of the earth, there is a perpetual emanation of heat, which supports the fluidity of the waters, and produces the temperature of the earth. In the interior parts of the earth, therefore, a heat exists, which is proper to it, and which is totally independent of that communicated by the sun.

We might confirm this general fact by a number of particular ones. Every man has remarked, that the snow melts in all places where the vapours of the interior parts of the earth have a free issue, as over pits, covered aqueducts, vaults, cisterns, &c., while in all other places, where the earth, bound up by the frost, intercepts these vapours, the snow not only remains, but, instead of melting, freezes. This circumstance is alone sufficient to show, that these emanations from the internal parts of the earth have a real and sensible degree of heat.

With regard to the fourth fact: after the satisfactory proofs we have given in several articles of our Theory of the Earth, it is apparent,

that the materials of which the globe is composed are of the nature of glass. This general truth, which we can prove by experience, was not altogether unknown to Leibnitz, a German philosopher, whose name will continue to be an honour to his country:

"Sane plerisque creditum et a sacris etiam scriptoribus insinuatum est, conditos in abdito telluris ignis thesauros. . . . . Adjuvant vultus, nam omnis ex fusione SCORIÆ VITRI est GENUS. . . . . . Talem vero esse globi nostri superficiem (neque enim ultra penetrare nobis datum) reapse experimur, omnes enim terræ et lapides igne vitrum reddunt . . . . . nobis satis est admoto igne omnia terrestria in VITRO FINIRI. Ipsa magna telluris ossa nudæque illæ rupes atque immortales silices cum tota fere in vitrum abeant, quid nisi concreta sunt ex fusis olim corporibus et prima illa magnaque vi quam in facilem adhuc materiam exercuit ignis naturæ . . . . . cum igitur omniaque non avolant in auras tandem funduntur, et speculorum imprimis urentium ope, vitri naturam sumant, hinc facile intelliges vitrum esse velut TERRÆ BASIN, et naturam ejus cæterorum plerumque corporum larvis latere. *G. G. Leibnitii* protogæa. *Goettingae*, 1749, p. 4 et 5."

The basis of minerals, of vegetables, and of animals, consists of vitrifiable matter; for all their *residua* may be ultimately converted into glass. The substances called *refractory* by chemists, and which they consider as not fusible, because they resist the action of their furnaces

without being changed into glass, may, notwithstanding, be vitrified by the more intense heat of burning-glasses. Hence all the materials of this glòbe, at least all those which are known to us, have glass for their basis, and may be ultimately reduced to their primitive state.

We have, therefore, proved the original liquefaction by fire of the whole mass of this globe, agreeably to the most rigorous rules of logic: 1. *A priori*, by the first fact, namely the elevation of the earth at the equator, and its depression at the poles. 2. *Ab actu*, by the second and third fact, namely, the internal heat of the globe which still subsists. 3. *A posteriori*, by the fourth fact, which shows the effect of this action of fire, *i. e.* glass, in all terrestrial substances.

But, though the materials which compose this globe have originally been of a vitreous nature, and may all be reduced to glass, they ought to be distinguished from each other with regard to the different states in which they are found before they are converted into glass by the action of fire. They should, in the first place, be divided into vitrifiable and calcarious substances. The first undergo no change by fire, unless it be pushed to such a degree of intensity as is sufficient to reduce them to glass; but an inferior degree of heat reduces the others to lime. The quantity of calcarious substances, though very considerable, is small when compared to those which are vitrifiable. The fifth fact above laid down, proves, that calcarious bodies have been

formed at a different period, and by another element; and we evidently perceive, that all the matters which have not been produced by the immediate action of the primitive fire, have been formed by the intervention of water; because they are all composed of shells and other relics of marine bodies. Under the class of vitrifiable substances are comprehended pure rock, quartz, sand, free-stone, granite, slates, clays, metals, and metallic minerals. These substances form the genuine basis of the globe, and compose its principal and greatest part. The whole of them have been originally produced by the primitive fire. Sand is nothing but glass in powder; slates, dried clays, pure rock, free-stone, and granite, are only vitreous masses, or vitrifiable sand in a concreted form. Flints, crystals, metals, and most other minerals, are only distillations, exudations, or sublimations of the first matters, all of which unfold their primitive origin and their common nature, by their aptitude of being converted into glass.

But calcarious sand and gravel, chalk, brown free-stone, marble, alabaster, calcarious spatha, both opaque and transparent, in a word, every substance which can be converted into lime, do not at first exhibit their original nature. Though, like all the others, they proceed from glass, calcarious bodies have passed through filtres, which have changed their appearance. They have been formed by water. They are composed entirely of madrepores, shells, and other relics of aquatic animals, which alone

are capable of converting fluids into solids, and of transforming the water of the sea into stone. Common marble and other calcarious stones are composed of entire shells and fragments of shells, of madrepores, astroites, &c., all the parts of which are either still evident, or easily recognisable. Gravel is nothing but broken fragments of marble and calcarious stones, which frost and the action of the air detach from the rocks; and they are equally convertible into lime. Lime may also be made of shells, chalk, and light land-stone. Alabaster, and those marbles which contain alabaster, may be regarded as large stalactites, which are formed at the expense of other marbles and common stones. Calcarious spatha is likewise formed by exudation or distillation from calcarious substances, in the same manner as rock crystal originates from vitrifiable matters. All this may be proved by inspecting these different substances, and by examining attentively the great monuments of nature.

MONUMENT FIRST.

Shells and other productions of the ocean are found on the surface and in the interior parts of the earth: and all the substances called *calcarious* are composed of the remains of these marine bodies.

MONUMENT SECOND.

In examining those shells and other marine productions found in France, Britain, Germany, and all the other parts of Europe, we discover, that most of the animals to which these remains have belonged, are not to be found in the adjacent seas, and that these species either have now no existence, or are to be found only in the southern seas. In the same manner, we see, in slates and other substances, at great depths, impressions of fishes and plants, none of which belong to our climates, and which either do not exist, or are to be met with in southern climates only.

MONUMENT THIRD.

In Siberia, and other northern regions of Europe and Asia, we find the skeletons, tusks, and bones of elephants, hippopotami, and rhinoceroses, in quantities sufficient to convince us, that these animals, which at present can propagate only in the southern regions, formerly existed and propagated in northern countries; and it has been remarked, that these remains of elephants, and other terrestrial animals, are found at inconsiderable depths below the surface. But shells and other marine bodies are buried deep in the interior parts of the earth.

MONUMENT FOURTH.

The tusks and bones of elephants, as well as the teeth of the hippopotamus, are found, not only in the northern parts of our continent, but likewise in those of North America, though the species of the elephant and rhinoceros have now no existence in the New World.

MONUMENT FIFTH.

In the middle of continents, and in places most remote from the sea, we find an infinite number of shells, most of which belong to animals actually existing in the southern ocean, and several others have no known representatives; so that their species seem to have been annihilated by causes till now unknown.

By comparing these monuments with the facts, we at once perceive, that the time when vitrifiable substances were formed is much more remote than that of the formation of calcarious bodies; and may now distinguish four, and even five epochs of the remotest antiquity: the first, when the matter of the globe was in fusion by fire, when the earth assumed its form, and the equator was elevated and the poles depressed by its rotatory motion: the second, when this matter consolidated, and formed the great masses of vitrifiable substances: the third, when the sea

covered the whole land now inhabited, and nourished shell animals, the remains of which have formed calcarious bodies: the fourth, when the waters which cover our continents retired to their proper basins: a fifth epoch, the indications of which are equally clear as the other four, is the time when the elephant, the hippopotamus, and other southern animals, inhabited the regions of the north. This epoch is evidently posterior to the fourth, since the relics of terrestrial animals are found near the surface of the earth, whilst those of marine animals are generally, and even in the same places, buried at great depths.

What, will any man maintain, that elephants, and other animals now peculiar to the south, have formerly inhabited the regions of the north? This fact, however singular and extraordinary it may appear, is not the less certain. Great quantities of ivory have been, and daily are found in Siberia, in Russia, and in other northern countries of Europe and Asia. These tusks of the elephant are found some feet below the earth, or they are exposed by the waters when they break down the banks of rivers. We find tusks and bones of the elephant in so many places, and in such quantities, that they never could be brought into such cold regions by human power. From incontestible and reiterated proofs, we are obliged to acknowledge, that these animals were formerly natives of the north, as they are now of the south. What renders this fact more mar-

vellous and more difficult to explain, we find the remains of those animals, now peculiar to the south of the Old Continent, not only in our northern provinces, but likewise in Canada and other parts of North America. In the Royal Cabinet there are several tusks and many bones of the elephant which were found in Siberia. We have other tusks and bones of the same animal which were found in France; as well as teeth of the hippopotamus discovered in America, near the river Ohio. Hence these animals, which cannot subsist in cold countries, have formerly existed in northern climates. Of course, the frozen zone was at that period equally warm as our torrid zone is at present; for it is impossible that the bodily constitution and real habits of these animals, which are the most permanent and invariable things in nature, should so far change as to bestow the temperature of the rein-deer upon the elephant. Neither can we suppose that these southern animals, which require much heat for their subsistence, could ever live and multiply in northern regions, if the climate were equally cold as it is at present. M. Gmelin, who travelled in Siberia, and there collected many bones of the elephant, supposes that vast inundations in the south had driven the elephants to the north, where they would all perish at once by the rigour of the climate. But this cause is not proportioned to the effect. More ivory, perhaps, has already been brought from the north than all the elephants of India now existing could furnish. Much more will be discovered when the vast deserts of the

north, which are scarcely known, shall be peopled, and the earth cultivated and dug by the hands of man. Besides, it is extremely improbable, that these animals should take the route which is most repugnant to their nature; for, if they were pushed by inundations from the south, why did they not rather fly to the east and west? Why did they fly as far as the sixtieth degree of north latitude, when they might have stopt on the road, or turned aside to more fortunate climates? And how is it possible to conceive, that, by an inundation from the southern ocean, the elephants were chased 1,000 leagues into the Old Continent, and more than 3,000 into the New? It is impossible that an inundation from the Indian ocean should drive the elephants into Canada, or even into Siberia; and it is equally impossible, that they should arrive in such numbers as are indicated by their remains.

Dissatisfied with this explication, I imagined that a more plausible one might be given, and which should perfectly correspond with my theory of the earth. But, before exhibiting my ideas on this subject, I shall, to prevent mistakes, remark,

1. That the ivory found in Siberia and in Canada unquestionably belongs to the elephant, and not to the morse or sea-cow, as some voyagers have pretended. In the northern regions, we likewise find the fossil ivory of the morse; but it is different from that of the elephant; and they are easily distinguished by comparing their internal texture. The tusks,

the grinders, the scapulæ, the thigh bones, and other bones found in the northern climates, certainly belong to the elephant; it is even impossible to hesitate concerning the identity of the species. The large square teeth discovered in the same northern countries, the grinding side of which resembles the spade painted on cards, have every mark of the *dentes molares* of the hippopotamus; and those enormous teeth, the grinding side of which is composed of large blunt points or protuberances, have belonged to some terrestrial animal that now no longer exists, like the great volutes, called *cornua ammonis*, which at present exist not in the ocean.

2. The bones and tusks of these ancient elephants are every way as large as those of the Indian elephants, to which we have compared them. This is a proof that these animals did not inhabit the northern regions from any necessity, since they acquired, in that situation, their full growth and complete dimensions. Of this fact we may be ascertained by the descriptions and dimensions of them given by M. Daubenton under the article *Elephant*. But, since that time, I have had transmitted to me an entire tusk and some fragments of fossil ivory, the length and breadth of which greatly exceed the tusks of the common elephant. I searched all the shops of the Paris ivory-merchants; but I found no tusk which could be compared to that in my possession. But, of a great number, I found only one equal to those sent from Siberia, whose circumference at the base is nineteen

inches. Ivory, which is taken from living elephants, or from recent skeletons found in the forests, is denominated *raw ivory;* and the appellation of *roasted ivory* is given to that extracted from the earth, the quality of which is more or less altered, according to the time it has remained under ground, or according to the quality of the earth in which it has been buried. Most tusks which come from the north are still very solid, and very fine works may be made of them. The largest were sent to us by M. de l'Isle, an astronomer, and member of the Royal Academy of Sciences. He collected them in his travels through Siberia. In all the shops of Paris, there was not a single tusk of raw ivory which measured nineteen inches in circumference: they were all smaller. This tusk was six feet and an inch in length; and it appears, that those in the Royal Cabinet, which were found in Siberia, were, when entire, more than six feet and a half: but, as their extremities were cut off, we could only make a near guess at their real length.

If we compare the thigh bones found in the same northern countries, we shall be satisfied that they are at least equally long, and considerably thicker, than those of the Indian elephants.

Besides, as formerly remarked, we have made an exact comparison of the bones and tusks sent from Siberia with those of the skeleton of an elephant, and we found that all these bones are evidently the relics of these animals. The Siberian tusks have not only the figure, but the

genuine structure of elephant ivory, which M. Daubenton describes in the following terms:

"When an elephant's tusk is cut transversely, we see, at or near the centre, a black point, called the *heart*. But, if the tusk is cut where it is hollow, there is only a round hole in the centre. We perceive crooked lines, which extend in different directions from the centre to the circumference, and, by crossing, form small lozenges. At the circumference, there is commonly a narrow circular band. The crooked lines ramify in proportion as they recede from the centre. Hence the size of the lozenges is nearly the same throughout. Their sides, or at least their angles, are of a more lively colour then the areas, doubtless because their substance is more compact. The band at the circumference is composed of straight and transverse fibres, which, if prolonged, would terminate in the centre. It is the appearance of these lines and points which is considered as the grain of the ivory. This grain is perceptible in all ivories; but it is more or less distinct in different tusks; and, when the grain is sufficiently apparent, the ivory gets the name of *large grained*, to distinguish it from that whose grain is fine."

It cannot be supposed that elephants could be transported into Siberia by men; for the state of captivity alone, independent of the rigour of the climate, would have reduced them to a fourth or a third of the dimensions which their remains exhibit. Of this effect we have sufficient proof

from the comparison we have made between an entire skeleton of an elephant in the Royal Cabinet, which had lived sixteen years at Versailles, with the tusks of other elephants brought from their native country. This skeleton, and those tusks, though of considerable size, are one half smaller than the tusks and skeletons of those which live in freedom in Asia or in Africa; and, at the same time, they are at least two thirds smaller than the bones of the same animals found in Siberia.

3. The great quantities of ivory already discovered by accident in countries nearly desert, and where no man searches for it, show that it is neither by one nor by several accidents, nor at one and the same time, that some individuals of this species have found their way into the northern regions, but that the species had formerly existed and multiplied there, in the same manner as they now exist and multiply in southern latitudes.

The only question, therefore, which remains to be solved, is, Whether there is or has been a cause that could so change the temperature of the different parts of the globe as to render the northern regions, which are now extremely cold, equally warm as the southern climates?

Some philosophers may imagine that this effect has been produced by the change in the obliquity of the ecliptic; because, at first sight, this change seems to indicate, that, as the inclination of the axis of the globe is not permanent, the earth might formerly revolve round an axis so dif-

ferent from that on which it now turns, as to make Siberia then lie immediately under the equator. Astronomers have observed, that the change in the obliquity of the ecliptic is about forty-five seconds in a century. Hence, by supposing this augmentation to be constant and successive, sixty centuries would produce a distance of forty-five minutes, and 3,600 centuries would produce a change of forty-five degrees. Such an alteration would bring back the sixtieth degree of latitude to the fifteenth, *i. e.* the country of Siberia, where the elephants formerly existed, to the regions of India, where they still exist and multiply. Now, it may be said, we have only to admit this long lapse of time in order to account for the regular abode of elephants in Siberia; it is 360,000 years ago since the earth revolved round an axis forty-five degrees distant from that upon which it turns at present: the fifteenth degree of latitude was then the sixtieth, &c.

I answer, that this idea, and the mode of explication which results from it, cannot, upon examination, be supported. The change in the obliquity of the ecliptic is not a constant and successive diminution and augmentation. On the contrary, it is a limited variation, and sometimes on one side and sometimes on the other; and, consequently, can never produce, on any side, or in any climate, this difference of forty-five degrees of inclination; for the variation in the obliquity of the earth's axis is occasioned by the action of the planets, which alter the situation of the ecliptic, without affecting the equator. To take

the strongest of these attractions, which is that of Venus, it would require 126,000 years to make a change of 180 degrees in the ecliptic of that planet, and, of course, to produce an alteration of six degrees forty-seven minutes in the real obliquity of the earth's axis; since six degrees forty-seven minutes are the double of the inclination of the orbit of Venus. In the same manner, the action of Jupiter cannot, in 93,600 years, change the obliquity of the ecliptic above two degrees thirty-eight minutes; and still this effect is in part compensated by the preceding. Hence it is impossible that this change in the obliquity of the earth's axis should ever amount to six degrees, unless we suppose, that the orbits of all the planets should likewise change; a supposition which we cannot or ought not to admit, since no cause exists which could produce this effect.

But I am enabled to solve this difficult matter, and to deduce it from an immediate cause. We have already seen, that the terrestrial globe, when it first assumed its form, was in a state of fluidity, and that the water being unable to dissolve terrestrial bodies, this fluidity was a liquefaction occasioned by fire. Now, to pass from this burning and liquefied state to a mild and temperate heat, time was necessary. The globe could not at once cool to its present temperature. Thus, during the first ages after its formation, the heat proper to the earth was infinitely greater than that which it received from the sun; since it is still much greater. This immense fire being

afterwards gradually dissipated, the polar, like all other climates, underwent successive changes from heat to cold. Of course, a certain time, or rather a long tract of time, existed, during which the northern regions, after having burnt like all others, enjoyed the same heat which at present is felt in the southern climates. Hence these northern countries might, and actually have been inhabited by animals now peculiar to the south, and to whom this degree of heat is indispensable. The fact, therefore, instead of being extraordinary, perfectly accords with the other facts, and is no more than a consequence of them. Instead of opposing my theory of the earth, this fact, on the contrary, is an accessory proof of its reality, and confirms the most obscure point I have advanced; *i. e.* when we attempt to look back into that profundity of time, when the light of genius is apt to extinguish itself, and when, for want of observations, genius has no aid to lead us to a more remote period.

A sixth epoch, posterior to the other five, is that when the two continents were separated from each other. It is certain, that they were not separated when the elephants lived equally in the north of Europe, Asia, and America; I say, equally; for we find their bones in Siberia, in Russia, and in Canada. Hence the separation of the two continents happened posterior to the abode of these animals in the northern regions. But, as we likewise find the tusks of the elephant in Poland, in Germany, in France, and in Italy, we must conclude, that, in proportion

as these northern regions cooled, the elephants retired toward the temperate zone, where the heat of the sun, and the greater thickness of the globe, compensated the loss of the earth's internal heat; and that, in the progress of time, the temperate zone having also become too cold, the elephant gradually migrated to the climates under the torrid zone, which alone have longest preserved, by the greater thickness of the globe, a superior degree of internal heat. These are likewise the only climates where this interior heat, united with that of the sun, is still sufficient to support their existence, and to permit them to propagate their species.

Independent of the specimens transmitted from Russia and Siberia, and which are preserved in the Royal Cabinet, there are many others in private collections. Vast numbers of them are to be seen in the Musæum of Petersburgh, as appears from a catalogue printed in the year 1742. There are likewise many of them in the British Musæum, in that of Copenhagen, and in some other collections in Britain, Germany, and Italy. This northern ivory, like the southern, is used in manufacturing many articles of hardware, &c. Hence the great quantity of the tusks and bones of elephants found in Siberia and Russia can no longer remain a doubtful point.

M. Pallas, a learned naturalist, in his late journey through Siberia, found a great quantity of elephants' bones, and an entire skeleton of a

rhinoceros, which was buried a few feet only under the surface of the ground.

"Enormous bones of the elephant were lately discovered at Swijatoki, seventeen versts from Petersburgh: they were found in a spot which had long been covered with water. Hence some prodigious revolution must have changed the climate, the productions, and the animals, in every quarter of the globe. These medals of Nature prove, that those countries which are now desolated by the rigours of intense cold, have formerly enjoyed all the advantages of the southern latitudes *."

The discovery of the tusks and skeletons of elephants in Canada is but recent; and I was first informed of them by a letter from the late Mr. Collinson, fellow of the Royal Society of London, of which the following is a translation:

"Mr. George Croghan has assured me, that, in the course of his travels through the countries bordering upon the river Ohio, in the years 1765 and 1766, about four miles south-east from this river, and 640 miles distant from Fort du Quesne or Pitsburgh, he saw in the neighbourhood of a large salt marsh, where the wild animals assemble at certain seasons of the year, immense bones and teeth. Having carefully examined the place, he discovered,

* Journal de Politique et de Literature, 5 Jan. 1776, art. Petersburgh.

in a high bank on the side of the marsh, a prodigious number of bones, which, from their figure and magnitude, appeared to be the bones and tusks of elephants.

" But, sir, the large grinding teeth which I send you, were found along with these tusks. There are others still larger than these, which seem to indicate, and even to demonstrate, that they belong not to elephants. How shall we reconcile this paradox? May we not suppose that there formerly existed a large animal, which had the tusks of an elephant and the grinders of the hippopotamus? for these large grinders are very different from those of the elephant. From the great number of tusks and grinders which he saw, Mr. Croghan thinks, that there must have been at least thirty of these animals buried in this place. Elephants, however, were never known in America; and it is improbable that they could be brought there from Asia. The impossibility of their living in countries where the winters are so rigorous, but where great quantities of their bones are found, makes a paradox, which your great sagacity may perhaps explain.

" Mr. Croghan, in the month of February, 1767, sent to different persons in London the bones and teeth he had collected in the years 1765 and 1766.

" 1. To my lord Shelburn, two large tusks, one of which was entire, and near seven feet long: its thickness exceeded not that of a common tusk of an elephant of an equal length.

"2. A jaw bone with two grinders in it, beside several enormous separate grinders.

"To Dr. Franklin, 1. Three tusks, one of which was about six feet long. It had been broke through the middle, which was corrupted, and resembled chalk. The others were sound. The end of one of them was sharpened to a point, and it consisted of very fine ivory.

"2. A small tusk, about three feet long, and as thick as a man's arm, with the depressions made by the muscles and tendons, which were of a bright chesnut colour, and appeared to be as fresh as if recently taken from the head of the animal.

"3. Four grinders, one of the largest of which was broader than those I sent you, and had likewise an additional row of knobs. All those presented to my lord Shelburn and Dr. Franklin were of the same form, and had the same enamel, as the specimens I now transmit for your examination.

"Dr. Franklin lately dined with an officer, who had brought from the same place, in the neighbourhood of the river Ohio, a tusk which was whiter, more lustrous, and more entire than any of the others; and likewise a grinder still larger than any of those I have mentioned *."

* Letter from Mr. Collinson to M. de Buffon, dated Mill Hill, near London, July 3, 1767.

Extract from a Journal of a Voyage made by Mr. Croghan on the River Ohio, and transmitted to Dr. Franklin in the Month of May, 1765.

" Having passed the great river Miame, we arrived, in the evening, at the place where the bones of elephants are found. It is about 640 miles from Fort Pitt. In the morning, I went to the large marsh where the wild animals assemble at certain times of the year. We came to this place by a road beaten with the feet of the wild oxen, or bisons. It is about four miles south-east from the river Ohio. We saw a great number of bones, some of them scattered about, and others buried five or six feet below the surface. We saw them in a bank of earth along the side of the road. We found two tusks of six feet in length, which we carried to our hut, along with other bones and teeth. The following year we returned to the same place in order to procure a greater number of tusks and teeth.

" If M. de Buffon had any queries to make upon this subject, I entreated him," says Mr. Collinson, " to transmit them to me; I shall send them to Mr. Croghan, a man of integrity and parts, who will be happy to answer every question." This little memoir was subjoined to the letter which I have just now quoted, and to which I shall add an extract of what Mr. Col-

linson formerly wrote me concerning these American bones:

"About a mile and a half from the river Ohio, there are six enormous skeletons buried on end, with tusks from five to six feet long, and of the same form and substance as elephants' tusks. They were thirty inches in circumference at the root. They tapered to a point. But, as they were broken, we could not perceive how they were joined to the jaws. A thigh bone of the same animal was found entire. It weighed a hundred pounds, and was four and a half feet in length. The tusks and thigh bones show that the animal must have been of a prodigious magnitude. These facts have been confirmed by Mr. Greenwood, who saw the six skeletons in the salt marsh. In the same place, he likewise found large grinders, which appeared not to belong to the elephant, but rather to the hippopotamus. Some of these teeth he sent to London, among others, two of which together weighed 9¼ pounds. He says, that the jaw bone was too heavy to be carried by two men. The interval between the orbits of the eyes was eighteen inches. An Englishman, who had been taken prisoner by the savages, and conducted to this salt marsh in order to teach them how to make salt by evaporating the water, declared, that, from a peculiar circumstance, he remembered to have seen these enormous bones. He told, that three Frenchmen, who were breaking nuts, sat upon a single thigh bone."

Some time after writing these letters, Mr. Collinson read to the Royal Society of London two short essays on the same subject, in which I found some new facts, which I shall relate, and add elucidations of such things as may require explanation:

"The salt marsh where the elephants' bones are found is about four miles distant from the banks of the river Ohio; but it is more than 700 miles from the nearest coasts of the sea. There is a road beaten by the wild oxen, or bisons, large enough to allow two chariots to travel abreast. This road leads directly to the great salt marsh, where these animals, as well as stags and other species of the deer, assemble at a certain season of the year to lick the earth and drink the salt water. . . . . . The elephants' bones are found in a bank of about six or seven feet high, which surrounds the marsh. There we see teeth and bones which had formerly belonged to some animals of a prodigious size. Some of the tusks are near seven feet in length, and consist of excellent ivory; and therefore we cannot entertain any doubt that they really belong to the elephant species. It is singular, however, that, among these tusks, we never meet with a single grinder of an elephant, but a vast number of enormous teeth, each of which has five or six blunt knobs, and must have belonged to some animal of an immense size. These square teeth have no resemblance to the grinders of the elephant, which are flat, and four or five times broader

than thick; so that these enormous grinders have no resemblance to the teeth of any known animal."

This last remark of Mr. Collinson is extremely just: these large grinders are totally different from those of the elephant; and, by comparing them with the grinders of the hippopotamus, which they resemble by their square figure, we shall perceive that they likewise differ in size, as they are two, three, and even four times more voluminous than the largest teeth of the ancient hippopotami found in Siberia and Canada, though these last teeth are three or four times larger than those of the hippopotami which now exist. All the teeth which I have examined in four heads of these animals preserved in the Royal Cabinet, have the grinding side hollowed in the form of a card spade, and those found in Canada and Siberia have the same character, and differ from them in size only. But those enormous teeth with large blunt knobs have always four and sometimes five rows; whilst the largest teeth of the hippopotamus have only three, as may be seen by comparing the figures of plate iii. iv. and v. with those of plate vi. It seems, therefore, to be certain, that these large teeth have never belonged either to the elephant or to the hippopotamus: the difference in size, though enormous, would not prevent us from regarding them as pertaining to this last species, if all the characters in their form were the same; since we know, as formerly remarked,

other square teeth three or four times larger than those of the present existing hippopotami, and which, having precisely the same characters, are unquestionably the teeth of hippopotami that have been three times larger than those whose heads are in the Royal Cabinet. I mean those large teeth, which really belong to the hippopotamus, when I remarked, that they were equally found in both continents, as well as the tusks of the elephant. It is remarkable, however, that we not only find real tusks of the elephant, and real teeth of the large hippopotamus, in Siberia and Canada, but we likewise find in the same countries those enormous teeth with four rows of large blunt knobs. We may, therefore, conclude, that this immense animal no longer exists, and that the species is entirely extinct.

M. le Compte de Vergennes, minister and secretary of state, was so obliging as to give me, in the year 1770, the largest of all these teeth, which is represented in plates iii. and iv.; it weighed eleven pounds four ounces. This immense tooth was discovered in making a ditch in Little Tartary. There were other bones which could not be collected, and, among these, a thigh bone, of which one half only was entire, and the cavity of this half contained fifteen Paris pints of water. M. l'Abbé Chappe, of the Academy of Sciences, brought me from Siberia a similar tooth but smaller, and which weighed only three pounds twelve ounces and a half. (Plate v.

fig. 1 and 2.) Lastly, the largest of those transmitted to me by Mr. Collinson, and which is represented, plate vi., was found, among several others, near the river Ohio in America; and they perfectly resemble other specimens brought from Canada.

From all these facts it is apparent, that, independent of the elephant and hippopotamus, whose relics are equally found in the two continents, another animal, common to both, has formerly existed, the size of which has greatly exceeded that of the largest elephants; for the square form of these enormous grinders shows, that they were numerous in each jaw; and, supposing there were only six or even four in each side of the jaws, we may form some notion of the magnitude of a head which could contain sixteen grinders, each weighing ten or eleven pounds. The elephant has only four grinders, two on each side. They are flat, and occupy the whole jaw; and these two flat grinders of the elephant surpass by two inches only the breadth of the largest square tooth of the unknown animal, which is double the thickness of those of the elephant. Thus every circumstance leads us to think, that this ancient species, which ought to be regarded as the largest of all terrestrial animals, existed during the first ages only; for an animal much larger than the elephant could not be so concealed in any part of the earth as to remain perfectly unknown. Besides, it is evident, from the figure of these

241-1

Plate 5

215
241-3

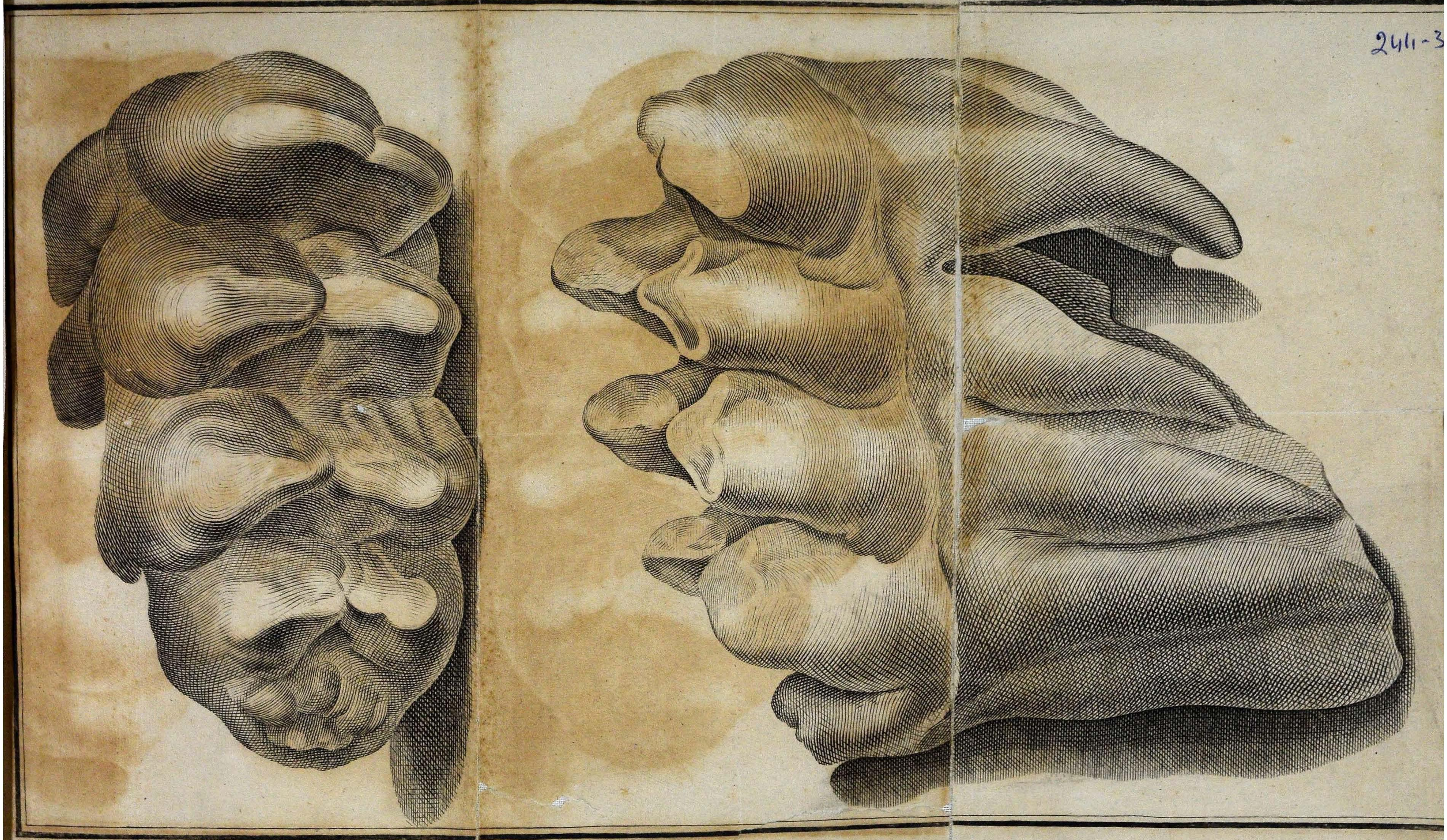


Plate 4

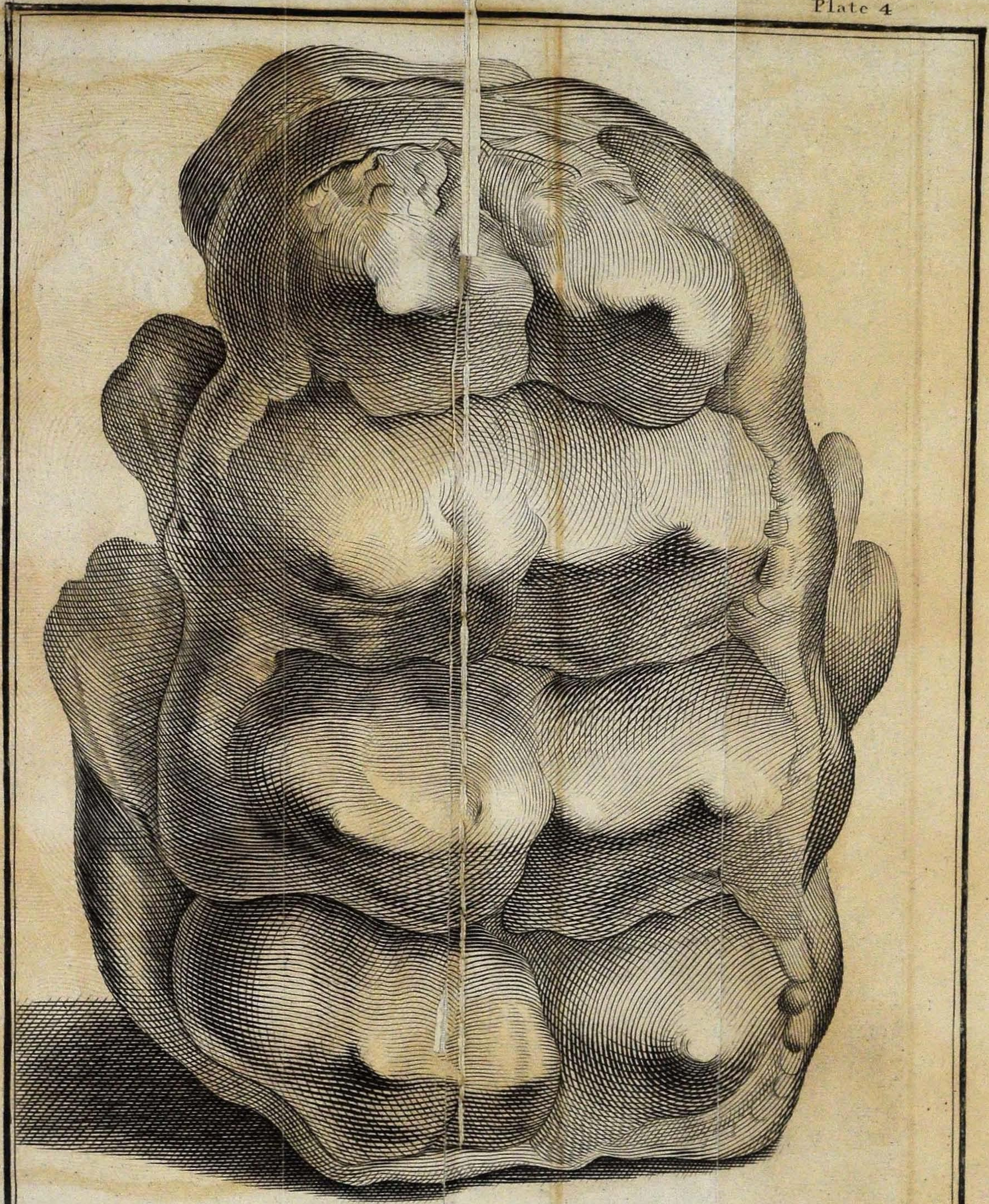
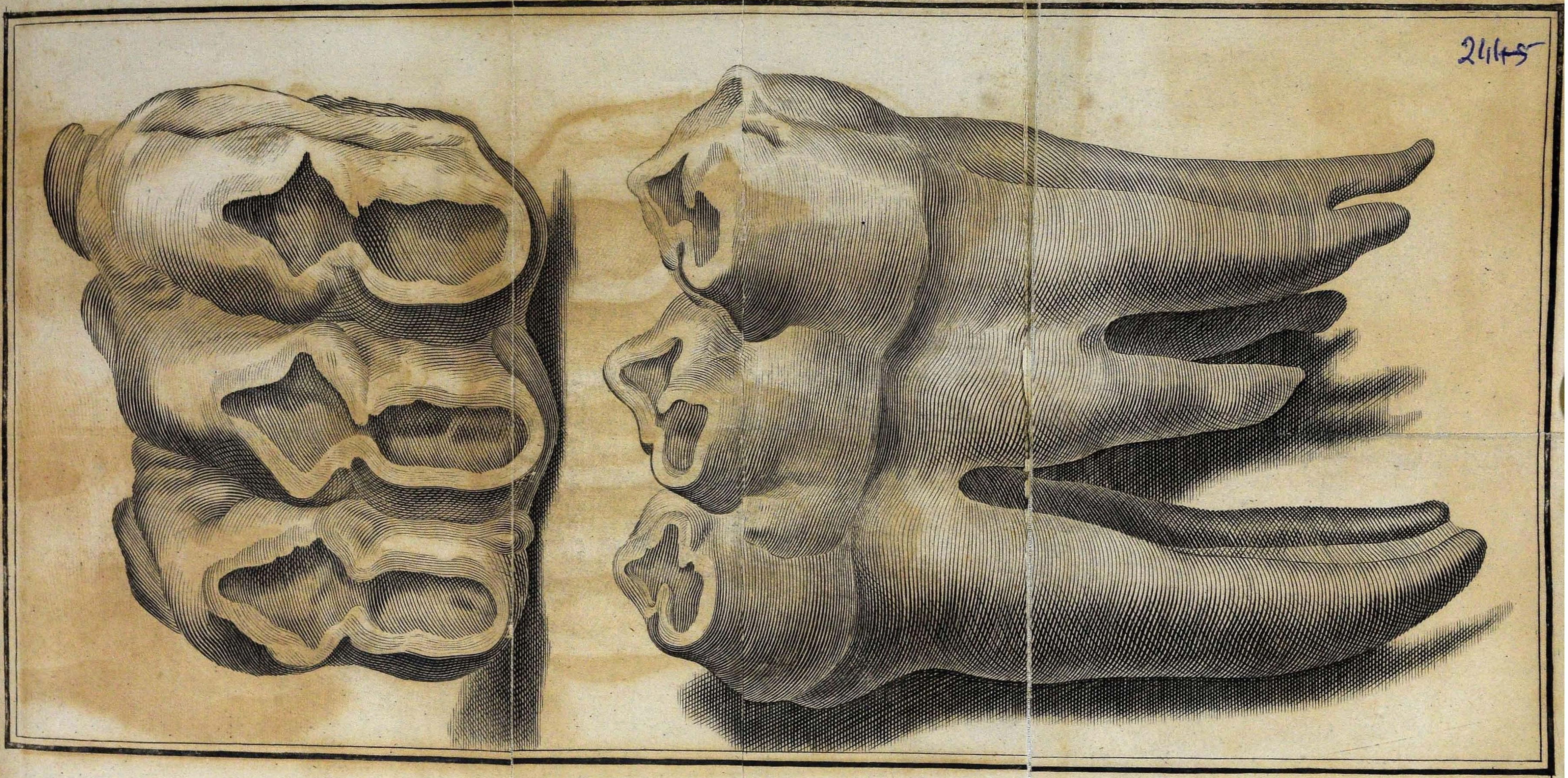


Plate 7

2445



244-4

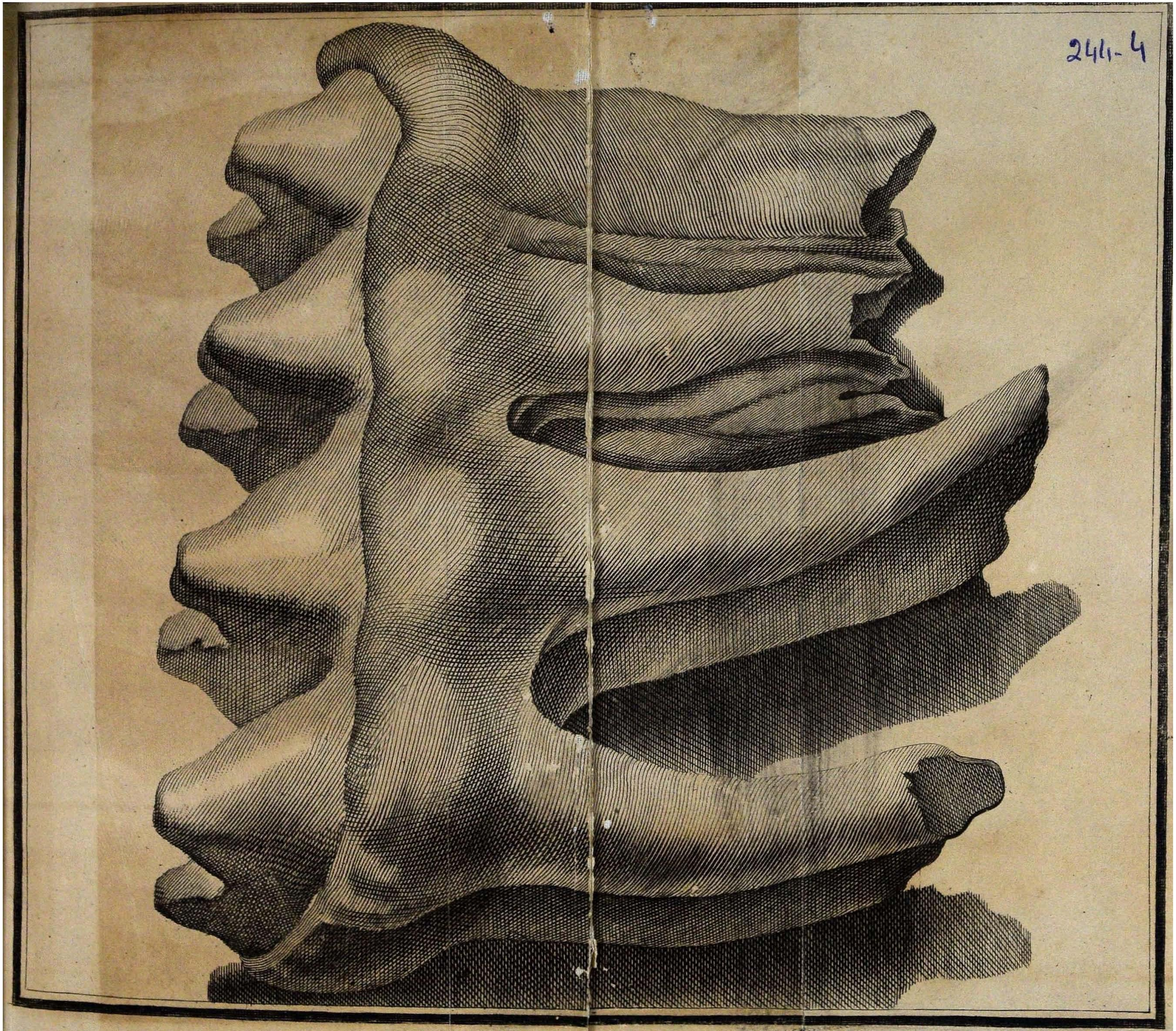


Plate 8

244-

teeth, as well as from the enamel, and the disposition of their roots, that they have no relation to the teeth of the cetaceous tribes; and that they have really belonged to a land animal, whose species made a nearer approach to that of the hippopotamus than to any other.

In the course of his essay, Mr. Collinson informs us, that several members of the Royal Society were equally well acquainted with the elephants' tusks daily found in Siberia, upon the banks of the Oby, and other rivers of that country. What system, he adds, can be formed, which will, with any degree of probability, account for those bones of the elephant found in Siberia and in America? He concludes with enumerating the weight and dimensions of all the teeth brought from the salt marsh near the river Ohio, the largest of which belonged to Captain Ourry, and weighed six pounds and a half.

Mr. Collinson, in his second essay, read before the Royal Society of London, December 10, 1767, remarks, that, as one of the tusks found in the salt marsh was striated or furrowed near the thickest end, he entertained some doubts whether these furrows were peculiar to the elephant species. To satisfy himself on this head, he visited the warehouse of a merchant who dealt in all kinds of teeth; and, after examining them, he discovered that there were as many tusks furrowed as smooth at the thick end; and, of course, he had no difficulty in pronouncing, that the tusks

found in America were, in every respect, similar to those of the African and Asiatic elephants. But, as the large American square teeth have no relation to the grinders of the elephant, he thinks, that they are the remains of some enormous animal which had tusks like an elephant, and grinders peculiar to its own species, their magnitude and form being totally different from those of any known animal*.

In the year 1748, M. Fabri, who had made great excursions into the northern parts of Louisiana and the southern regions of Canada, informed me, that he had seen heads and skeletons of an enormous quadruped, called by the savages, the *father of oxen*; and that the thigh bones of these animals were from five to six feet in length. Some time after, and previous to the year 1767, specimens of these large teeth, belonging to the unknown animal, as well as those of the hippopotamus, and bones of the elephant, all found in America, were transmitted to Paris. The number of them is too considerable to leave any doubt that these animals formerly existed in the northern regions of America, as well as in those of Europe and Asia.

But elephants have likewise existed in all the temperate countries of our continent. I mentioned tusks found in Languedoc near Simore, and those discovered in Cominges in Gascony. To these I shall add the largest and finest of the

* Phil. Trans. 1767.

whole, lately sent to the Royal Cabinet by the duc de la Rochefoucauld, whose zeal for promoting science is a result of his general knowledge. This excellent specimen he found, along with M. Desmarets, of the Academy of Sciences, when viewing the fields in the environs of Rome. This tusk was divided into five fragments, which the duc de la Rochefoucauld ordered to be collected. One of these fragments was stolen by the porter who had the charge of it, and there remained only four, which were about eight inches in diameter. When laid together, these four fragments were seven feet in length; and we learn, from M. Desmarets, that the fifth fragment, which was lost, was near three feet long. Hence the total length of the tusk must have been about ten feet. By examining the broken ends, we discovered every character of elephantine ivory; though, by being long buried under ground, it has become light and friable, like all other fossil ivories.

M. Tozzetti, a learned Italian naturalist, relates, " that there were found, in the valleys of Arno, the bones of elephants and other terrestrial animals, in great quantities, scattered here and there in the strata of the earth. We may, therefore," he remarks, " conclude, that elephants were formerly natives of Europe, and especially of Tuscany *."

" We found," says M. Caliellini, " about the

* Extrait d'une Lettre du Dr. Tozzetti; Journal Etranger, mois de Decembre, 1755.

end of November, 1759, in a country estate belonging to the marquis de Petrella, situated at Fusigliano, in the territory of Cortona, a fragment of an elephant's bone mostly encrusted with a stony matter. . . . . . Similar fossil bones have formerly been discovered in our environs.

"In the cabinet of M. Galeotto Corazzi, there is another large portion of a petrified elephant's tusk, which was lately found in the neighbourhood of Cortona, at a place called La Selva. . . . . . Having compared these fragments with a piece of an elephant's tusk lately brought from Asia, we found that the resemblance between them was perfect.

"In the month of April last, M. l'Abbé Mearini brought me an entire jaw bone of an elephant, which he had found in the district of Farneta, a village belonging to this diocese. This jaw bone is mostly petrified, and particularly on the two sides, where the stony incrustation rises an inch above the surface, and has all the hardness of a stone.

"Lastly, I am indebted to M. Muzio Angelieri Alticozzi, a gentleman of this town, for a thigh bone of an elephant, which is almost entire. He discovered it in one of his country estates called Rota, which is situated in the territory of Cortona. This bone is a Florence fathom long, and is likewise petrified, particularly in the upper extremity, called the head *."

* Lettre de M. Louis Coltellini de Cortone; Journal Etranger, mois de Juillet, 1761.

In the same manner, we find in France, and in all the other nations of Europe, skeletons and vertebræ of marine animals, which can only subsist in the most southern seas. The same change of temperature, therefore, has happened in the various parts of the ocean as well as in those of the land: and this second fact, like the first, as it proceeds from the same cause, confirms the whole.

When we compare those ancient monuments of the first age of animated Nature with her actual productions, we evidently perceive that the constituent form of each animal has remained the same, and that there is no alteration in the principal parts of their structure. The type of each species has suffered no change. The internal mould has invariably preserved its form. However long we may suppose the succession of time, whatever number of generations may have passed, the individuals of each kind still exhibit the same forms as those of the first ages, especially in the larger species, whose characters are more fixed, and whose nature is more permanent; for the inferior species have, as formerly remarked, been sensibly affected by the different causes of degeneration. We must, however, remark, with regard to the larger species, such as the elephant and hippopotamus, that, by comparing their ancient remains with those of our times, we, in general, perceive that these animals were then much larger than they are at present. Nature was then in her primitive vigour. The internal heat of the earth bestowed

on its productions all the vigour and magnitude of which they were susceptible. The first ages produced giants of every kind. Dwarfs and pigmies succeeded, after the earth had cooled; and if, as other monuments seem to indicate, some species of animals, which formerly existed, are now lost, this effect could only be produced, because their nature required a greater degree of heat than what is now felt in the torrid zone. Those enormous and nearly square grinders with blunt knobs, those large cornua ammonis, of which some are several feet in diameter, and many other fossil fishes and shells, which no longer have any living representatives, existed only in those primitive times when the earth and sea were still warm, and produced and nourished animals to whom this degree of heat was necessary, and who exist not at present, because they have probably perished by cold.

To know all the petrifactions of which there are no living representatives, would require long study and an exact comparison of the various species of petrified bodies, which have been found in the bowels of the earth. This science is still in its infancy. We are certain, however, that there are many of those species, such as the cornua ammonis, ortoceratites, lenticular and numismal stones, belemnites, Judaic stones, anthropomorphites, &c., which cannot be referred to any species now existing. We have seen cornua ammonis of two and three feet in diameter; and we have been assured, by men worthy of credit, that a cornua ammonis has been found in Cham-

pague larger than a mill-stone, since it was eight feet in diameter and one foot thick. I had an offer of its being sent to me. But the enormous weight of this mass, which is 8,000 pounds, and its great distance from Paris, prevented me from accepting the present. These examples, and others which might be given, are sufficient to show, that many species of shell and crustaceous animals formerly existed in the sea, of which there are now no living representatives. The same observation is applicable to some of the scaly fishes. Most of those found in certain slates have so little resemblance to the fishes with which we are acquainted, that their species cannot be ascertained. Even those in the Royal Cabinet, which are perfectly preserved in masses of stone, cannot be referred to any of our known species. It appears, therefore, that the sea formerly nourished many genera, whose species no longer exist.

But, with regard to terrestrial animals, we have only a single example of a lost species, and it appears to have been the largest, without excepting even the elephant: and, since the examples of lost species are more rare in land than in marine animals, is it not probable that the production of the former was posterior to that of the latter?

From these facts and monuments we may perceive six successive epochs in the first ages of Nature; six species of duration, the limits of which, though indeterminate, are not the less real; for these epochs are not like those of

civil history, marked by fixed points, or limited by centuries and other portions of time, which admit of an exact measurement. They may, however, be compared between themselves, and their relative duration may be estimated by other facts and monuments, which indicate contemporary dates.

* * * * * *

After finishing his preliminary discourse, the count de Buffon proceeds to state the different epochs of Nature, which he divides into seven great periods.

EPOCH FIRST.

When the earth and planets first assumed their proper form.

EPOCH SECOND.

When the fluid matter consolidated and formed the interior rock of the globe, as well as those great vitrifiable masses which appear on its surface.

EPOCH THIRD.

When the waters covered all the continents.

EPOCH FOURTH.

When the waters retired, and volcanos began to act.

EPOCH FIFTH.

When the elephants, and other animals of the south, inhabited the northern regions.

EPOCH SIXTH.

When the continents were separated from each other.

EPOCH SEVENTH, and last.

When the power of man assisted the operations of nature.

These epochs are purely hypothetical, and depend more or less on the notion, that the earth and planets were originally driven from the body of the sun by the impulse of a comet, and, of course, remained long in a state of liquid fire. We shall therefore content ourselves

with having barely mentioned them, and proceed to enumerate some facts and positions, which, though applied in support of a fanciful system, are curious, and may be useful.

The count de Buffon remarks, that the cavities and eminences of the globe have been encrusted, and sometimes filled with metallic substances, which are still found in these situations.

"Metallic veins," says M. Eller, "are found only in elevated places, in a long chain of mountains. This chain of mountains is always supported by a basis of hard rock. As long as this rock preserves its continuity, there is no chance of discovering metallic veins. But, when we meet with crevices or fissures, we then entertain hopes of finding metal. Mineralogists have remarked, that, in Germany, the most favourable situation is when the mountains rise gradually, stretch toward the south-east, and, after attaining their greatest elevation, descend gently toward the north-west. . . . .

"It is generally in a rugged rock, the extent of which is often unlimited, but split into fissures, that metals are found sometimes pure, but generally in the state of ores. These fissures are commonly encrusted with a white shining substance, called *quartz* by the miners: when heavier, but soft and laminated, nearly like chalk, it receives the denomination of *spar*. It is surrounded, on the side next the rock, with a kind of slime, which seems to nourish these quartzy or sparry earths. These two coverings serve as a sheath for the vein. The more perpendicular

the vein, the more is to be expected from it. Whenever the miners find a perpendicular vein, they say that it will be very productive.

"In these fissures and cavities, metals are formed by a perpetual and pretty strong evaporation. The vapours which issue from mines show that this evaporation is still going on. Fissures which have no exhalation are commonly barren of metal. The most certain proof that the exhaling vapours carry along with them mineral particles, and apply them to the sides of the fissures, is that successive encrustation, which is apparent in the whole circumference of these fissures or hollows of rocks, till their cavities are completely filled, and the solid vein is formed. This fact is still farther confirmed by the tools left in these hollows; and, several years after, they are found to be encrusted with metal.

"The fissures which furnish the richest veins of metal always incline to a perpendicular direction. In proportion as the miners descend, the temperature of the air is always warmer; and the exhalations are sometimes so abundant and so noxious, that, in order to avoid suffocation, the miners are obliged to fly to the pits or galleries, otherwise they would be instantly destroyed by the arsenical and sulphureous particles. Sulphur and arsenic are commonly found in the four imperfect, and in all the semimetals, and it is from these they receive their metallic form.

"Gold, and sometimes silver and copper, are

the only metals which are found pure in any quantities. But, in general, copper, iron, lead, and tin, when taken out of the veins, are mineralized with sulphur and arsenic. We know, from experience, that metals lose their metallic form by degrees of heat proportioned to each species. This destruction of the metallic form, which the four imperfect metals undergo, shows that the basis of metals is an earthy matter; and, as these calces, as well as the calcarious and gypseous earths, vitrify by the application of a certain degree of heat, we are certain that metallic earth belongs to the class of vitrifiable earths *."

M. Lehman, a celebrated chemist, is the first person who suspected that metallic substances had a double origin. "Gold and silver," he remarks, "are found in masses only in the mountains which have veins, and iron is found only in those mountains which have regular strata. All the small pieces of gold and silver found in the mountains with strata have been detached from veins in the superior mountains in the neighbourhood of the former.

"Gold is never in the form of ore. It is always found in a native or virgin state, though it is often scattered about in particles so minute, that it cannot be distinguished even by the best microscopes. In the mountains with strata, no gold, and very little silver, are to be found. These

* Mem. de M. Eller sur l'Origine et la Generation des Metaux.

two metals belong exclusively to mountains with veins. Sometimes, however, we find silver in small leaves, or under the form of haïr, in slate. Native copper oftener occurs in slate; and this copper is also commonly in the form of threads or hair.

" A few years after iron ores have been taken from the earth, they are reproduced. They are not found in the mountains with veins, but in those with strata. Iron is seldom, if ever, met with in a native state.

" With regard to native tin, it has no existence in nature, and is only produced by the assistance of fire. The same remark is applicable to lead, though the grains found in Silesia have been considered as native lead.

" Native mercury is found in strata of fat argillaceous earth, or in slate.

" The silver ores found in slate are not nearly so rich as those found in the mountains with veins. This metal is found in beds of slate; and is always in the form of minute particles, threads, or ramifications, but never appears in large masses. These beds of slate must likewise be adjacent to the mountains with veins. The silver ores found in strata are never in a solid or compact form. All the other ores, which contain much silver, are peculiar to the mountains with veins. There is a great deal of silver in the strata of slate; and it is also sometimes found in pit-coal.

" Tin is the metal which most rarely appears in strata; lead is more common in that situa-

tion. We find it attached to slate, but never to coal.

"Iron is almost universally diffused, and is found in beds under a number of different forms.

"Cinnabar, cobalt, bismuth, and lapis calaminaris, are likewise commonly found in beds.

"Pit-coal, jet, amber, and aluminous earth, are produced by vegetables, and especially by resinous trees which have been buried in the earth, and have been more or less decomposed; for we often find, above the strata of coal, wood which is not totally decomposed; and it is still more decomposed as we descend deeper. Slate, which covers coal, is often full of the impressions of plants, such as ferns, maiden-hair, &c. It is remarkable, that all these impressions belong to foreign plants, and the wood likewise appears to be foreign. Amber, which ought to be regarded as a vegetable resin, often includes insects, which, when attentively examined, belong not to the climate where they now exist. Aluminous earth is frequently laminated, and resembles wood sometimes more and sometimes less decomposed.

"Sulphur, alum, and sal ammoniac, are found in beds formed by volcanos.

"Petroleum and naphtha indicate a subterraneous fire, which produces a distillation from pit-coal. We have examples of these subterraneous fires which act silently, in the coal strata of Britain and Germany. They burn long without any explosion; and it is in the neighbourhood of these subterraneous fires that hot springs are found.

"The mountains which contain veins include neither coal nor bituminous and combustible bodies: these substances are found only in the mountains with strata."

In the second epoch of Nature, the count de Buffon remarks, "that, in the northern regions there are mountains composed entirely of iron." I mention, says he, by way of example, the iron mines near Taberg in Smoland, a part of the island of Gothland in Sweden. It is the most remarkable of those mines, or rather mountains of iron, which have the quality of yielding to the attraction of the loadstone; which proves that they have been formed by the action of fire. The basis of this mountain is a very fine sand. Its height is more than 400 feet, and its circumference about one league. It is composed entirely of a rich ferruginous matter, and we even find in it native iron, which is another proof that it has undergone the action of a violent fire. This ore, when broken, exhibits small shining particles, which sometimes cross each other, and sometimes are arranged like scales. This mine has been wrought above 200 years.

The ore in this mountain is not disposed in regular beds; neither is the iron every where of equal goodness. Through the whole mountain there are fissures sometimes perpendicular and sometimes horizontal: these are all filled with sand, which contains no iron. This sand is pure, and of the same species with that on the sea-coast. In this sand, we sometimes find the bones of animals, and the horns of stags, which

shows that the sand has been carried thither by the waters, and that the formation of this iron mountain by fire happened before the crevices and the perpendicular and horizontal fissures were filled with sand.

The masses of ore are rolled down from the top of the mountain; but, in other mines, the minerals must be drawn up from the bowels of the earth. This ore must be broken to pieces, or pounded, before it is put into the furnace, where it is smelted by means of charcoal and calcarious stones.

This hill of iron is situated in an elevated and mountainous district, about eighty leagues from the sea: it seems to have formerly been altogether covered with sand *.

We are next informed, that there are mountains of loadstone in some countries, and particularly in those of the north. From the foregoing example, we have seen that the iron mountain of Taberg rises 400 feet above the level of the sea. M. Gmelin, in his travels through Siberia, remarks, that, in the northern countries of Asia, almost all the metallic ores are found on the surface of the earth, whilst in other countries they are buried deep in the interior parts. This fact, if generally true, is a new proof that metals have been formed by the primitive fire, and that the globe, being less thick in

* Extrait d'un article de l'Ouvrage periodique qui a pour titre, *Norsdilcke beytrage*, &c. Contribution du Nord pour les Progrés de la Physique, de Sciences, et des Arts, 1756.

the northern regions, metals were formed nearer the surface than in the southern countries.

M. Gmelin examined the great mountain of loadstone among the Baschkires in Siberia. This mountain is divided into eight parts by valleys, of which the seventh part produces the best loadstone. The summit of this portion of the mountain consists of a yellowish stone, which seems to partake of the nature of jasper. We there find stones that have the appearance of free-stone, which weigh from 2,000 to 3,000 pounds; but they all have a magnetic virtue. Though covered with moss, they fail not, at more than the distance of an inch, to attract iron and steel. The sides exposed to the air have the strongest magnetic power, those covered with the earth being much weaker. Those parts which are exposed to the injuries of the air are softer, and, consequently, less proper for being armed. A large portion of loadstone, of the size above mentioned, is composed of a number of other portions, which act in different directions. To work them properly, they should be separated in such a manner that the whole portion, which includes the virtue of each particular magnet, should preserve its unity: by observing this rule, we would probably obtain magnets of an uncommon strength. But, as they are cut without any foresight, many portions are of no value, either because they contain little or no magnetic power, or because, in a single piece, there are two or three magnets

united: such portions have indeed a magnetic virtue; but, as it is not directed to the same point, a magnet of this kind must be subject to great variations.

The loadstone of this mountain, except what is exposed to the air, is exceedingly hard, spotted with black, and full of little knots or protuberances, consisting of small angular parts, like those often observable on the surface of bloodstone, from which it differs only in colour; but, instead of these angular parts, we sometimes perceive a kind of ochery earth. In general, loadstones with these angular parts have less power than the other kinds. That part of the mountain where the loadstones are found is composed almost entirely of a fine iron ore, which lies in small portions among the loadstones. The whole section of the high part of the mountain contains a similar ore; but, in proportion as we descend, the metal is more rare. Below the ore of loadstone, there are other ferruginous stones, which, if melted, would produce very little iron. These stones have the colour of metal, and are very heavy. Their interior parts are irregular, and have nearly the appearance of scoriæ. In their surfaces they pretty much resemble loadstones; but they have no magnetic power. Between these stones there are other pieces of rock which appear to be composed of small particles of iron. The stone itself is heavy, but very soft. The interior parts resemble burned matter, and they have little or no magnetic vir-

tue. We likewise meet occasionally with a brown iron ore in beds of an inch thick; but it yields very little metal *.

In the mountains of Poias, in Siberia, there are several other mines of loadstone. Ten leagues off the road which leads from Catharinbourg to Salikamskaia, there is a hill called Galazinski, which is more than twenty fathoms high, and is entirely composed of a loadstone rock. It has the brown colour and the density of iron.

Twenty leagues from Salikamskaia, we find cubical loadstones of a brilliant greenish colour. When pulverised, the grains have the appearance of fire. It is worthy of remark, that loadstone is found only in those chains of mountains which stretch from south to north †.

In the countries bordering upon Lapland, and on the confines of Bothnia, two leagues distant from Cokluanda, there is an iron ore, from which very fine loadstones are extracted. "We admired," says Regnard, "the surprising effects of this stone, when it remained in its natural situation. It required a great deal of force to obtain pieces of the magnitude we wished; and the large hammer employed remained so fixed to the wedge in the stone, that the workman required assistance to disengage it. I tried the

* Extrait d'Hist. Generale des Voyag[illegible], tom. viii. p. 141, &c.

† Ibid. tom. xix. p. 472.

experiment myself; I took a large iron lever, which was so heavy that I could hardly support it; I brought it near the wedge, by which it was attracted and supported with an amazing force. I held a mariner's compass in the middle of the hole where the ore lay, and the needle revolved perpetually with an incredible rapidity*.

In vol. i. p. 30, I remarked, "that, according to the relation of voyagers, the mountains of the north are but small hills when compared to the mountains of the equatorial regions; and that the general movement of the waters produced those large mountains in the Old Continent, which stretch from east to west, and from north to south in the New."

This passage requires explanation, as well as some restrictions. From a thousand observations, it is certain, that shells and other productions of the ocean, are found upon the whole surface of the inhabited parts of the earth, and even upon the mountains to a very great height. I advanced, from the authority of Woodward, who first collected facts upon this subject, that shells were likewise found upon the tops of the highest mountains. From my own observations, as well as those of others, I know, that there are shells in the Alps and Pyrennees at 900, 1,000, 1,200, and 1,500 fathoms above the level of the sea; that they are likewise found in the

* Oeuvres de Regnard, tom. i. p. 185.

mountains of Asia; and, lastly, in the Cordeliers of America, a bank of shells has lately been discovered at the height of more than 2,000 fathoms above the sea *.

It is, therefore, certain, that, in all the different parts of the world, and even to the height of 1,500 or 2,000 fathoms above the present level of the sea, the surface of the globe has been covered with the waters, and that they remained long enough for the production and multiplication of shell animals; for the quantity of them is so great, that their spoils often form large banks, which extend many miles in length. They compose a considerable part of the exterior strata of the earth; for calcarious substances, or the spoils of shells, are very common in most

* M. le Gentil, of the Academy of Sciences, wrote me the following letter, in December, 1771: "Don Antonio Ulloa desired me, when departing from Cadiz, to send him two petrified shells, which, in the year 1761, he had dug out of the mountain that contains the quicksilver mines. This mountain is in the government of Ouanca-Velica in Peru. Its southern latitude is from 13 to 14 degrees. At the place where these shells are found, the mercury stood at 17 inches $1\frac{1}{4}$ line, which corresponds to the height of $2,222\frac{1}{3}$ fathoms above the level of the sea.

"At the top of the mountain, which is far from being the highest in this canton, the mercury stands at $16\frac{1}{2}$ inches, which implies a height of $2,337\frac{2}{3}$ fathoms.

"In the town of Ouanca-Velica, the mercury stands at 18 inches $1\frac{1}{2}$ line, which gives a height of 1,94[illegible] fathoms.

"Don Antonio Ulloa informed me, that he detached these shells from a very thick bank, the extent of which he did not know: the shells are of the large pilgrim or scallop kind."

countries. But, at high points of elevation, *i. e.* above 1,500 or 2,000 fathoms, the summits of the mountains generally consist of pure rock, granite, and other vitrifiable bodies, produced by the primitive fire, which contain no shells, madrepores, or any thing that has a relation to calcarious substances. We may, therefore, conclude, that the sea has never reached, or at least for a short time only, those most elevated parts of the earth.

To support the testimony of Don Ulloa, concerning the shells found in the Cordeliers, we shall add that of Alphonso Barba. He tells us, that, in the most mountainous parts of Peru, there are shells of all sizes, some of them concave, others convex, and the whole finely impressed*. Hence America, as well as the other quarters of the globe, has been covered with the waters of the sea. The first observers were probably induced to think that no shells were to be found in the Cordeliers, because most of these mountains, which are the highest on this globe, are either active or extinguished volcanos, the eruptions of which have covered all the adjacent countries with burned substances; of course, all the shells which might have been found there, are not only buried, but completely destroyed. It is not, therefore, surprising that no marine productions have been discovered around these mountains, which either are at present, or have formerly been volcanos; for the territories

* Metallurgie d'Alphonso Barba, tom. i. p. 64.

which surround these mountains must be composed entirely of ashes, scoriæ, glass, lava, and other burned or vitrified bodies. Thus the notion that the sea never covered the mountains, has no other foundation than this circumstance, that, on the tops of several of them, no shells or other productions of the sea are now to be seen. But, as we find, in an infinite number of places, and even as high as 1,500 or 2,000 fathoms, shells and other sea bodies, it is evident, that there are few ridges of mountains which have not been covered with the ocean; and that the spots where no shells appear only show that the animals which produce them have never dwelt there, or that the motion of the waters has not transported thither marine productions, as it has done in every other part of the globe.

We are next informed, that some fishes and plants can live and vegetate in waters so hot as from fifty to sixty-three degrees of the thermometer. There are many examples of plants growing in the hottest bath waters; and M. Sonnerat found fishes in water the heat of which was so great that he durst not plunge his hand into it. "Two leagues from Calamba," says he, "I found, in the isle of Luçon, near the village of Bally, a brook, the water of which was so hot that Reaumur's thermometer, when plunged into it, about a league from its source, stood at the sixty-ninth degree. Upon perceiving such a degree of heat, I imagined, that all the productions of Nature must have been extinguished upon the margin of this brook. But I was much surprised when I

saw three vigorous shrubs, the roots of which were immersed in this boiling water, and their branches surrounded with its vapour. The heat was so great, that, when the swallows attempted to cross the water at seven or eight feet high, they uniformly fell down dead. One of these shrubs was an agnus castus, the other two were a species of broom called aspalathus. During my abode in this village, I constantly drank this water after it was cooled. Its taste seemed to be earthy and ferruginous. Several baths are constructed along this brook, and their degrees of heat are proportioned to their distance from its source. When I visited the first bath, my surprise was increased: in this water, which was so hot that I durst not plunge my hand into it, I saw fishes swimming. I used every effort to procure some of them; but their agility, and the want of address in the people, prevented me from succeeding. I examined them in the water; but I could not distinguish their genus, on account of the vapour rising from the water. They had brown scales, and the largest of them were about four inches long. I could not learn how these fishes had got into the baths." The testimony of M. Sonnerat is strengthened by that of M. Prevost, who travelled with him into the interior parts of the isle of Luçon. "You was right," M. Prevost remarks, "to communicate to M. de Buffon the observations you collected when we travelled together. You desired me to confirm in writing what surprised us so much in

the village of Bally, situated on the margin of the Laguna of Manilla, at Los-bagnos. I am sorry I have not a copy of our observations made with Reaumur's thermometer. But I clearly recollect, that the water of the small brook, which passed through this village to fall into the lake, made the mercury rise to sixty-six or sixty-seven degrees, though it was plunged into the water at a league's distance from the source of the brook. The margins of this brook were covered with a very fine green carpet. You cannot have forgot the agnus castus we saw in flower, the roots of which were moistened with the water of the brook, and its stem and branches perpetually surrounded with its steams. The curate of the village likewise assured me, that he had seen fishes in this same brook. This fact I cannot certify. But I saw fishes in one of the baths, the heat of which raised the mercury to forty-eight and [illegible] degrees*."

I know not [illegible]er fishes have ever been found in our [illegible]ers: but it is certain that the bottom [illegible]hottest of them is covered with plants. M. [illegible] Abbé Mazéas informs us, that, in the almost boiling water in the Solfatara of Viterbe, the bottom of the basin is covered with the same plants which grow at the bottoms of lakes and ditches †.

* Voyage à la Nouvelle Guineé par M. Sonnerat, Correspondent de l'Academie Royale des Sciences, et du Cabinet Roi, p. 38, &c.

† Mem. des Savans Etrangers, tom. v. p. 325.

Of Giants.

From monuments which still remain, it appears, that gigantic animals of different kinds have formerly existed.

The large teeth with blunt knobs which I formerly described, indicate the existence of an animal whose magnitude greatly surpassed that of the elephant. But this gigantic species is now entirely annihilated. Other large teeth, the grinding face of which resembles spades on cards, like those of the hippopotamus, and which are four times larger than the teeth of the present hippopotamus, show that there has been a very gigantic species of this animal. The enormous thigh bones, which far exceed the dimensions of those of our elephants, demonstrate the same thing with regard to the elephant species.

In the year 1772, t[illegible]as found, near Rome, a petrified head[illegible]x, which P. Jacquier describes in the [illegible]ng manner: "The length of the front, between the two horns, is two feet three inches; the distance between the orbits of the eyes, fourteen inches, and that from the superior part of the front to the orbit of the eye one foot six inches; the circumference of the horn at the base, is one foot six inches; the length of the horn four feet; and the distance between the ends of the horns three feet. The internal part of this petrifaction

is extremely hard. This head was found at Puzzolani more than twenty feet below the surface of the ground *.

"In the year 1768, I saw, in the cathedral of Strasburg, a large horn of an ox suspended by a chain to a pillar near the choir. It appeared to be three times bigger than those of our largest oxen. As it was hung very high, I could not take the exact dimensions, but I judged it to be about 4½ feet long, and from seven to eight inches in diameter at the base †."

Lionel Waffer relates, that he saw, in Mexico, bones and teeth of a prodigious size: among others, he saw a tooth three inches broad, and four in length. Having consulted the most intelligent people of the country, they concluded that the head could not be less than a yard broad ‡.

It is, perhaps, the same head which Acosta mentions: "I saw," says he, "a grinder which astonished me by its enormous size; for it was as large as a man's fist." P. Torquemado, a Franciscan, relates, that he had in his possession a grinder, twice as large as a man's fist, and which weighed two pounds. He adds, that, in the city of Mexico, and in the Convent of St. Augustine, he saw a thigh bone so large, that the

* Gazette de France du 25 Septembre, 1772, art. de Rome.

† Note communicated to M. de Buffon by M. Greignon, Sept. 24, 1777.

‡ Waffer's Travels in America, p. 367.

individual to which it belonged must have been from eleven to twelve cubits high, *i. e* seventeen or eighteen feet; and that the head must have been as big as one of the large pitchers used in Castille for holding wine.

Phillippe Hernandés informs us, that there were found, at Tezaco and Tosuca, several bones of an extraordinary magnitude; and that among these there are grinding teeth five inches broad and ten high; from which he concludes, that the size of the head must have been so enormous that two men could not have embraced it with their arms. Don Lorenzo Boturini Benaduci likewise tells us, that, in New Spain, and particularly in the heights of Santafé, and in the territories of Puebla and Ttlascala, they find enormous bones and grinders, one of which, preserved in the Royal Cabinet, is a hundred times larger than the largest human teeth *.

The author of this Gigantologie Espagnole attributes these enormous teeth and bones to giants of the human species. But, is it credible that men ever existed whose heads were eight or ten feet in circumference? Is it not equally astonishing, that, in the species of the hippopotamus or elephant, there have been individuals of this magnitude? We are, therefore, led to think, that these enormous teeth are of the same kind with those lately found in Canada near the river Ohio, which we ascribed to an unknown

* Gigantologie Espagnole, par le P. Torrubia, Journal Etranger, Nov. 1760.

animal, whose species formerly existed in Tartary, in Siberia, and in Canada, and which extended from the Illionois as far as Mexico. As the Spanish authors do not mention that elephants' tusks were found in New Spain along with these large grinders, it is probable that a species different from that of the elephant formerly existed there, to which these large grinders belonged, and that this species was diffused as far as Mexico. Besides, the large teeth of the hippopotamus seem to have been anciently known; for St. Augustine tells us, that he saw a grinder so large, that, if divided, it would have made 100 teeth of an ordinary man *. Fulgosa likewise remarks, that teeth were found in Sicily, each of which weighed three pounds †.

John Sommer relates, that he found, near Chatham in Canterbury, at the depth of seventeen feet below the surface of the earth, monstrous bones, some of them entire, and others broken. He likewise found four entire teeth, each of them weighing more than half a pound, and nearly as large as a man's fist. The whole four were grinders, and, except in magnitude, they pretty much resembled human teeth. He farther remarks, that Louis Vives mentions a grinder still larger, which was shown him for a tooth of St. Christopher. He adds, that Acosta saw in India a similar tooth dug out of the earth, along with several other bones, which, when ar-

* De Civitate Dei, lib. xv. cap. 9.

† Ibid. lib. i. cap. 6.

ranged in proper order, represented a man of a monstrous stature. "We might have formed the same idea," says Mr. Sommer, "concerning the teeth dug out of the earth near Canterbury, if bones had not been found in the same place, which did not belong to the human species." Several persons who examined these bones, judged them to be the bones and teeth of the hippopotamus. Two of these teeth are engraved in the Philosophical Transactions, num. 272, fig. 9.

From these facts we may conclude, that most of those large bones found under the surface of the earth belong to the elephant and hippopotamus: but it seems to be certain, that, by comparing the enormous teeth with blunt knobs with those of the elephant and hippopotamus, they have belonged to an animal much larger than either, and that the species of this prodigious animal no longer exists.

Among the present elephants, it is extremely rare to find a tusk of six feet in length. The longest are generally from five to six and a half feet; and, of course, the ancient elephant, which produced a tusk of ten feet long, whose fragments are in our possession, was a gigantic species. The immense thigh bone in the Royal Cabinet confirms the same conclusion.

The same remark is applicable to the species of the hippopotamus. I caused two of the largest grinders to be extracted from the largest head of the hippopotamus in the Royal Cabinet: one of them weighed ten, and the other nine and a half ounces. I then weighed two teeth, the one found

in Siberia, and the other in Canada. The first weighed two pounds twelve ounces, and the second two pounds two ounces. Hence these ancient hippopotami were gigantic when compared with those now existing.

The example already given of the enormous petrified head of an ox, found in the environs of Rome, proves, that there have likewise been prodigious giants in this species of quadruped, which we are also enabled to show by several other monuments of antiquity. In the Royal Cabinet, we have, 1. A fine, greenish horn, which is very smooth and well turned, and evidently belongs to the ox. The circumference at the base is twenty-five, and its length forty-two inches. Its cavity contains eleven and a quarter Paris pints of liquor. 2. The core, or internal bone of an ox's horn, which weighs seven pounds; whilst the largest core of the horns of our oxen exceeds not the weight of one pound: this internal bone was presented to the Royal Cabinet by M. le Comte de Tressan, a man of taste, and a good natural historian. 3. Two internal bones of an ox's horn, attached to a portion of the cranium, were found in beds of turf, at the depth of twenty-five feet, between Amiens and Abbeville, and transmitted to me for the Royal Cabinet. The whole weighed seventeen pounds; and each horn bone, when separated from the cranium, weighed at least seven and a half pounds. I compared the dimensions, as well as the weight of these different bones; that of the largest ox to be found in Paris was only thirteen inches long, and seven in circum-

ference at the base. But, of the two dug out of the earth, the one was twenty-four inches long, and twelve in circumference at the base, and the other twenty-seven inches in length, and thirteen in circumference. These facts are more than sufficient to show, that, in the species of the ox, as well as in those of the hippopotamus and elephant, prodigious giants have formerly existed.

With regard to the human species, individual giants have been produced not only in Asia, but in every climate; for, even in our own days, we see gigantic men in every country. We lately saw a giant who was born in Finland, on the very confines of Lapland. But we are not equally certain, that permanent races, and far less entire nations of giants, ever existed. However, the testimony of ancient authors, and especially those of Holy Writ, seem clearly to indicate, that races of giants formerly existed in Asia. In the book of Numbers, chap. xiii. verse 33, it is said, *And there we saw giants, the sons of Anak, which came of the giants: and we were in our own sight as grasshoppers, and so we were in their sight.* Though this description may have the appearance of exaggeration, which is common in the oriental style, it is plain that these giants were very large.

In 2 Samuel, chap. xxi. verse 20, a giant is mentioned of the race and family of Goliah, who had six fingers and toes on his hands and feet: in the same book there are several other passages which prove the existence and destruction of giants.

In Joshua, chap. ii. verse 22, it is said, that *there was none of* the giants of the race *of the Anakims left in the land of the children of Israel; only in Gaza, in Gath, and in Ashdod, there remained.*

Philo, St. Cyrillus, and several other authors, seem to think, that the word *giants* means only proud and impious men, and not men of an extraordinary stature. But there is no foundation for this opinion; since the amazing height and strength of these men are often described.

The prophet Amos informs us, that the Lord *destroyed the Amorite, whose height was like the height of cedars, and he was strong as the oaks.*

Ogg, king of Basan, was nine cubits high, and Goliah ten cubits and one palm. Ogg's bed was nine cubits, or thirteen and a half feet long, and four cubits, or six feet, broad. The breastplate of Goliah weighed two hundred and eight pounds four ounces, and the blade of his lance twenty-five pounds.

These evidences are sufficient to prove, that there formerly existed, in the continent of Asia, not only individuals, but races of giants, who have been destroyed, and the last of whom appeared in the days of king David. Nature, who never loses any of her rights, sometimes resumes her former powers of production; for, in almost every climate, men of an extraordinary stature, *i. e.* of seven and a half, eight, and even nine feet high, occasionally appear. Beside the examples already given, many others are to be found, both

in ancient and modern authors, of giants of ten, twelve, fifteen, and eighteen feet high. But these last dimensions, I am persuaded, ought to be greatly reduced. The bones of elephants have often been mistaken for human bones. Besides, Nature, in her present appearance, presents no species with such great disproportions, except, perhaps, that of the hippopotamus; for the teeth of those found in the bowels of the earth are at least four times larger than the teeth of the hippopotamus which now exists.

The bones of the supposed king Teutobochus, found in Dauphiny, gave rise to a dispute between Habicot, a surgeon in Paris, and Riolan, the famous anatomist. Habicot, in his *Gigantosteologie*, tells us, that these bones were taken out of a brick sepulchre, eighteen feet below ground, and surrounded with sand. He neither gives an exact description, nor the number of these bones. He asserts that they are human, because they belonged to no other animal. He adds, that some masons, when working for Seignior Langon, a gentleman of Dauphiny, on the 11th day of January, 1613, discovered this tomb near the ruins of the castle of Chaumont; that the tomb was built with brick; that it was thirty feet long, twelve broad, and eight high; that it was covered with a gray stone, on the middle of which was engraved, *Teutobochus Rex*; that, when the tomb was opened, a human skeleton appeared, which was 25½ feet long, ten broad at the shoulders, and five thick; that, before touching these

bones, the head was measured, and it was five feet in length, and ten in circumference. Here it is worthy of remark, that the proportion between the length of a human head and that of the body, is not a fifth, but a seventh and one half; so that this head of five feet supposes the body to have been 37½ feet in length. Lastly, Habicot tells us, that the under jaw was six feet round, and the orbits of the eyes seven inches: that each clavicle was seven feet long; and that most of these bones, after being exposed to the air, crumbled into dust.

In the same year, 1613, Dr. Riolan published a tract under the title of *Gigantomachie*, in which he maintains, that Habicot, in his Gigantosteologie, had given false measures of the body and bones of the pretended giant Teutobochus; that Riolan measured the thigh bone and the bone of the leg together with the astragalus joined to the calcaneum; that they exceeded not 6½ feet, even including the os pubis; and, of course, that the length of the giant could be only thirteen feet, instead of twenty-five. He then gives his reasons for denying these bones to be human; and concludes, that the bones exhibited by Habicot belong not to man, but to the elephant.

A year after the publication of Habicot's Gigantosteologie and Riolan's Gigantomachie, a pamphlet appeared under the title of *The Imposture, concerning supposed human Bones falsely attributed to King Teutobochus, discovered*. In this pamphlet, the bones are denied to be human, and

supposed to have been engendered by some virtue in the earth. Another pamphlet was published without a name, in which it is said, that, among these bones, some were human and others not.

In 1618, Riolan published his Gigantologie, in which he maintains, that the bones in question were not only not human, but that men in general were never larger than they are at present.

In the same year, Habicot replied to Riolan: he says, that he presented his Gigantosteologie to Louis XIII.; that, about the end of July, in the year 1613, the bones mentioned in this work were exposed to the eye of the public; and that they are real human bones. He quotes a number of examples from ancient and modern authors, to prove that men of immense stature have existed. He persists in maintaining, that the calcaneum, tibia, and femur of the giant Teutobochus, when joined to each other, were more than eleven feet in length.

He next gives letters written to him at the time these bones were discovered, and which seem to confirm the reality both of the tomb and of the bones of the giant Teutobochus. From a letter written by Seignior de Langon, dated St. Marcellin, in Dauphiny, and another by the Sieur Masurier, a surgeon at Beaurepaire, it appears, that silver coins were found along with the bones. The first letter contains the following passage: "As his majesty," says Seignior

de Langon, "is desirous of having the remaining bones of king Teutobochus, and the silver coins found in the tomb, I declare, that your adversaries are ill informed, and that, if they knew the matter more perfectly, they would not entertain any doubts that these bones really belong to the human species. The physicians of Montpellier came here, and would have given any money to purchase the bones. M. le Maréchal de Lesdiguieres made them be carried to Grenoble; and the physicians and surgeons of that place recognised them to be human bones. This fact, of course, can only be denied by persons who are ignorant of the real circumstances."

In this dispute, neither Riolan nor Habicot, the one a physician and the other a surgeon, have had sense enough to give an exact description of the bones in question. Both of them, actuated by passion and a party spirit, have written in a style which destroys all confidence in their assertions. Hence it is extremely difficult to ascertain the species to which these bones really belonged. But, if they were found in a brick tomb, with a stone cover, upon which the words *Teutobochus Rex* were inscribed; if coins were found in this tomb; if it contained but a single skeleton of twenty-four or twenty-five feet in length; and, if Seignior Langon's letter relates nothing but truth, the general fact, *i. e.* the existence of a giant of twenty-four feet high, unless we should suppose a very extraordinary concourse of falsehoods, could not admit of

a doubt. But the fact is by no means proved in a manner so explicit as not to leave room for much hesitation. It is true, that several authors, otherwise worthy of credit, have mentioned giants as large, and even larger. Pliny relates*, that, by an earthquake in Crete, a mountain was split, and discovered a human body of sixteen cubits long, which some ascribed to that of Otus, and others to that of Orion. Sixteen cubits are equal to twenty-four feet, which is the same length with the skeleton of king Teutobochus.

In a memoir of M. le Cat, an academician of Rouen, we have an enumeration of several giants of enormous magnitude; namely, two whose skeletons were found near Athens, of which one was thirty-six and the other thirty-four feet high; another of thirty was found in Sicily, near Palermo, in the year 1548; another of thirty-three feet was likewise found in Sicily, in the year 1550; and another was also found in Sicily, near Mazarino, which was thirty feet long.

These testimonies notwithstanding, it is difficult to believe that men of thirty or thirty-six feet high ever existed: it is perhaps too much to believe in the existence of giants of twenty-four feet high. However, evidences multiply, become more positive, and gradually increase, in proportion as the dimensions decrease. M. le Cat relates, that, in the year 1705, there was

* Lib. vii. cap. 16.

found, near the banks of the river Morderi, at the foot of Mount Crussol, the skeleton of a giant which measured 22½ feet; and that the Dominicans of Valencia have part of the tibia with the joint of the knee.

Platerus, a celebrated physician, asserts, that he saw at Lucerne the skeleton of a man, which was nineteen feet in length.

The giant Ferragus, slain by Rolland, nephew to Charlemagne, was eighteen feet high.

In the sepulchral caverns of the island of Teneriffe, a skeleton was found, which measured fifteen feet, and in whose jaws were eighty teeth. These three facts, as well as the preceding, are related in M. le Cat's Essay concerning Giants. He mentions another skeleton found in a ditch near the convent of the Dominicans at Rouen, the skull of which held a bushel of corn, and the bone of the leg was four feet long: the whole body, of course, must have been from seventeen to eighteen feet in length. Upon the tomb of this giant, the following inscription was engraved: "Here lies the noble and puissant seigniur le chevalier Ricon de Valmont, together with his bones."

In the Journal Littéraire of Abbé Nazari, we are told, that, in High Calabria, in the month of July, 1665, there was dug out of the gardens of Signior de Tiviolo, a skeleton of eighteen Roman feet long; that the head was 2½ feet; that each grinder weighed about an ounce and a third, and the other teeth three quarters of an

ounce; and that this skeleton was bedded in a mass of bitumen.

Hector Boethius, in his History of Scotland, relates, that the bones of a man, ironically called Little John, are still preserved, who was supposed to have been fourteen feet high.

In the Journal des Savans, *anno* 1692, there is a letter from P. Gentil, professor of philosophy at Angers, in which he says, that, having been informed of a gigantic body discovered nine leagues from the town of Lassé, he went to the spot to satisfy himself concerning the truth of the fact. He learned from the curate of the place, that, in digging his garden, a sepulchre was discovered which contained a body of seventeen feet two inches long. There was no skin on the body. This body had others between its arms and legs, which might have been the person's children. In the same place, there were discovered fourteen or fifteen other sepulchres, some of them ten feet, others twelve, and others fourteen feet long, which contained bodies of the same dimensions. The sepulchre of this giant continued exposed to the air more than a year; but, as it attracted too many visitors to the curate, he again covered it with earth, and planted three trees in the place. These sepulchres were constructed with a stone which resembled chalk.

Thomas Mollineux saw, in a cabinet at Leyden, a prodigious human frontal bone. From its junction with the nose to the sagittal suture,

it was $9\frac{1}{12}$ inches; its length was $12\frac{2}{10}$ inches, and its thickness half an inch, *i. e.* in every dimension it was double that of an ordinary frontal bone. Hence the person to whom this gigantic bone belonged must have been twice the common size of a man, or at least eleven feet high. This bone was unquestionably human; and it seemed not to have acquired this uncommon magnitude by the effects of any disease; for its thickness was exactly proportioned to its other dimensions, which never happens in diseased bones *.

M. Klein tells us, that he saw, in the cabinet of M. Witreu at Amsterdam, a frontal bone, from the dimensions of which it appeared, that the person to whom it appertained must have been thirteen feet four inches high, *i. e.* about 12½ French feet †.

After all these facts, I shall leave my readers in the same embarrassment as myself, with regard to the real existence of giants of twenty-four feet in length. I cannot persuade myself, that, at any time, or by any circumstances whatever, the human body could be elevated to such immoderate dimensions. But, at the same time, it is unquestionable, that giants of ten, twelve, and perhaps even of fifteen feet high, have existed; and it is almost certain, that, in the primæval ages of nature, not only gigantic individuals, but even permanent and successive

* Phil. Trans. num. 168, art. ii.

† Ibid. num. 456, art. iii.

races of giants, were produced, of which that of the Patagonians is the only remaining example.

To prove that some of the fishes and plants found in coal and slate belong to species which no longer exist, the count de Buffon produces the following facts and observations:

With regard to this subject, we shall remark, with M. Lehman*, that there are no impressions of plants in slate, except when it accompanies pit-coal; and that, on the contrary, impressions of fishes are seldom found but in coppery slates.

It has likewise been remarked, that, in the district of Mansfield, the beds of slate which contain petrified fishes, are covered with a stratum of stones called stinking stones. This stratum is a species of gray slate, which has derived its origin from stagnant water, where the fishes had corrupted before they were petrified †.

M. Hoffman, when treating of slates, says, that the petrified fishes found in these stones have not only been living creatures, but that the strata of slate have originated from muddy water, which, after fermenting and petrifying, subsided in thin laminæ or beds.

"In the slate of Angers," says M. Guttard,

* Tom. iii. p. 407.

† Leeberoth, Journal Oeconomique, Juillet, 1752.

"there are sometimes impressions of plants and fishes, which merit the greater attention, because the impressions of the plants represent marine fuci, or sea wreck, and those of the fishes represent different species of the crustaceous tribes, the impressions of which are more rare than those of scaly fishes, or shells." He adds, "that, after consulting several authors who treat of fishes and crustaceous animals, he could not discover any of them that resembled the impressions in question, except the sea louse, which has some resemblance to them; but it has thirteen rings, and the impressions on the slates have only seven or eight: the impressions of these fishes are generally interspersed with a whitish pyritous substance. It is remarkable, that in the slates of Angers, as well as in those of other countries, the impressions of fishes are frequent, and those of shells are exceedingly rare, whilst the latter are very common in limestone *."

Many proofs might be given that all pit-coal is compos[illegible] of the spoils of vegetables, mixed with bitu[illegible] and sulphur, or rather with the vitriolic [illegible] which is perceived when the coal is bu[illegible]ten find a great quantity of vege[illegible]per strata of coal; and in proportion [illegible]nd, we see traces of the decomposi[illegible] the same vegetables. There are species of coal which are not fossil wood: that found at Sainte Agnés, near Lons-le-Saunier,

* Mem. de l'Acad. des Sciences, ann. 1757, p. 52.

has a perfect resemblance to logs or trunks of fir, in which we distinctly perceive the marks of each year's growth, as well as the pith. These trunks differ only from common fir by being somewhat oval, and by their rings being concentric ellipses. They exceed not a foot in circumference, and their bark is very thick and full of furrows, like that of old firs. But the bark of common firs, of the same size, is always smooth.

"I found," M. de Gensanne remarks, "several veins of this kind of coal in the diocese of Montpellier: here the trunks are very large; their texture resembles that of chesnut trees from three to four feet in circumference. These fossils, when burning, have only a slight odour of asphaltum. Their flame and embers resemble those of wood. They are found near the surface of the earth, and commonly indicate the existence of real pit-coal at greater depths *."

These ligneous coals ought to be regarded as wood deposited in a bituminous earth, from which they derive their fossil quality. They are found only in earths of this kind, and alwa[illegible]s near the surface. They sometimes form th[illegible]ratum immediately above the seams of real [illegible] Some of them, which have been impr[illegible] small quantity only of bitumen, [illegible]ades and colour of wood. "I foun[illegible]," says M. de Gensanne, "at Cazarets, [illegible]nt Jean de Culcul, four leagues from Montpellier. But,

* Hist. Nat. du Languedoc, par M. de Gensanne, tom. i. p. 20.

when broken, this fossil commonly presents a smooth surface, perfectly similar to that of jet. In the same canton, near Aseras, there is fossil wood changed into a white ferruginous pyrites. The mineral matter occupies the heart of the wood; and we distinctly perceive the woody substance furrowed and partly dissolved by the mineral acid *.

After such proofs, related by M. de Gensanne himself, who is otherwise a good mineralogist, I acknowledge, that I was surprised to see him ascribe the origin of coal to clay more or less impregnated with bitumen. This notion is not only refuted by his own facts, but we shall be convinced by those I am about to relate, that we ought to attribute the origin of every species of coal to the spoils of vegetables mixed with bitumen.

I agree with M. de Gensanne, that neither this fossil wood nor turf can be considered as coal completely formed. That found near Lonsle-Saunier has been recently examined by the president de Ruffey, a learned academician of Dijon: he remarks, that this fossil wood makes a near approach to the nature of pit-coal; and that it is found within two or three feet of the surface through an extent of two leagues; that it is from three to four feet thick; that we easily distinguish the species of wood to be oaks, horn beams, and trembling poplars; that this wood is sometimes in the form of bundles or faggots;

* Hist. Nat. du Languedoc, tom. i. p. 54.

that the bark of the logs is well preserved; that the annual circles, the cuts made by the axes, and, at different distances, collections of chips are plainly distinguishable; that this wood converted into coal is excellent for soldering iron; that, when burning, it diffuses a fetid odour; and that alum has been extracted from it *.

"Near the village called Beichlitz, about a league from the town of Halle, two strata, composed of a bituminous earth and fossil wood (of which there are several mines in the country of Hesse), were discovered. It is similar to that found in the village of Sainte Agnés in Franche-comté, two leagues from Lons-le-Saunier. This mine is in the territory of Saxe. The first stratum lies at the depth of three fathoms and a half, and is from eight to nine feet thick. To arrive at it, we cut through a white sand, then a whitish gray clay, which is three feet thick: still deeper we meet with a considerable thickness both of sand and clay, which cover the second stratum. This stratum is only from three and a half to four feet thick. We sounded deeper, but found no other strata of that kind.

"These strata are horizontal; but they sink or rise nearly in the same manner as common strata. They consist of a brown bituminous earth, which is friable when dry, and resembles corrupted wood. Pieces of wood of all

* Mem. de l'Acad. de Dijon, tom. i. p. 47.

sizes are found, which, when taken from the mine, where they are soft, must be cut with an axe. This wood, when dry, breaks easily. When broke, it shines like bitumen; but we distinctly perceive in it the whole organization of wood. It is less abundant than the bituminous earth, and the workmen lay it aside for their own use.

"A bushel or two quintals of bituminous earth sells for eighteen or twenty French sous. In these strata there are pyrites; they are of a vitriolic nature; when exposed to the air they effloresce and turn white: but the bituminous matter is of little value, as it gives but a feeble heat *."

Hence this species of fossil wood, found so near the surface of the earth, must be a much more recent production than common pit-coal, which is almost constantly sunk very deep. But this idea does not preclude the ancient coal from being formed of the spoils of vegetables; since, in the deepest coal mines, we recognise woody substances, and several characters which belong to vegetables only. Besides, there are some examples of fossil wood found in large masses, and in extensive beds, under strata of free-stone and calcarious rocks. Hence there is no other difference between real pit-coal and those charred woods, but what arises from the degree of decomposition, and from a greater or smaller impregnation with bitumen. The basis of their

* Voyages Metalurgiques de M. Jars, p. 320.

substance is the same, and both derive their origin from the spoils of vegetables.

M. le Monnier, one of the king's physicians, and a learned botanist, found, in the schist or false slate, which traverses a large field of pit-coal in Auvergne, the impressions of several ferns, almost the whole of which were unknown to him: he only thought that he could distinguish the impression of the leaves of the ofmund-royal, of which he saw but one example in all Auvergne *.

It were to be wished that botanists would examine more accurately the impressions of plants found in pit-coal and in slate. The impressions of plants, as well as those of crustaceous animals, shells, and fishes, found in these minerals, should be drawn and engraved; for all this labour is necessary to enable us to determine the actual or the past existence of these species, or even their relative antiquity. At present, we are satisfied, that most of them are unknown; and that, in those which have been referred to known species, the differences are always so great as to create hesitation.

The count de Buffon remarks, that the motion of the waters from east to west has diminished the surface of the earth on the west side; and that, in every continent of the globe, the declivity is more rapid on the west than on the east coasts. This is evident in the continent of America, the declivities of which are extremely

* Observations de Hist. Nat. par M. le Monnier, p. 193.